& Use of Materials, Components & Finishes in Engineering Design

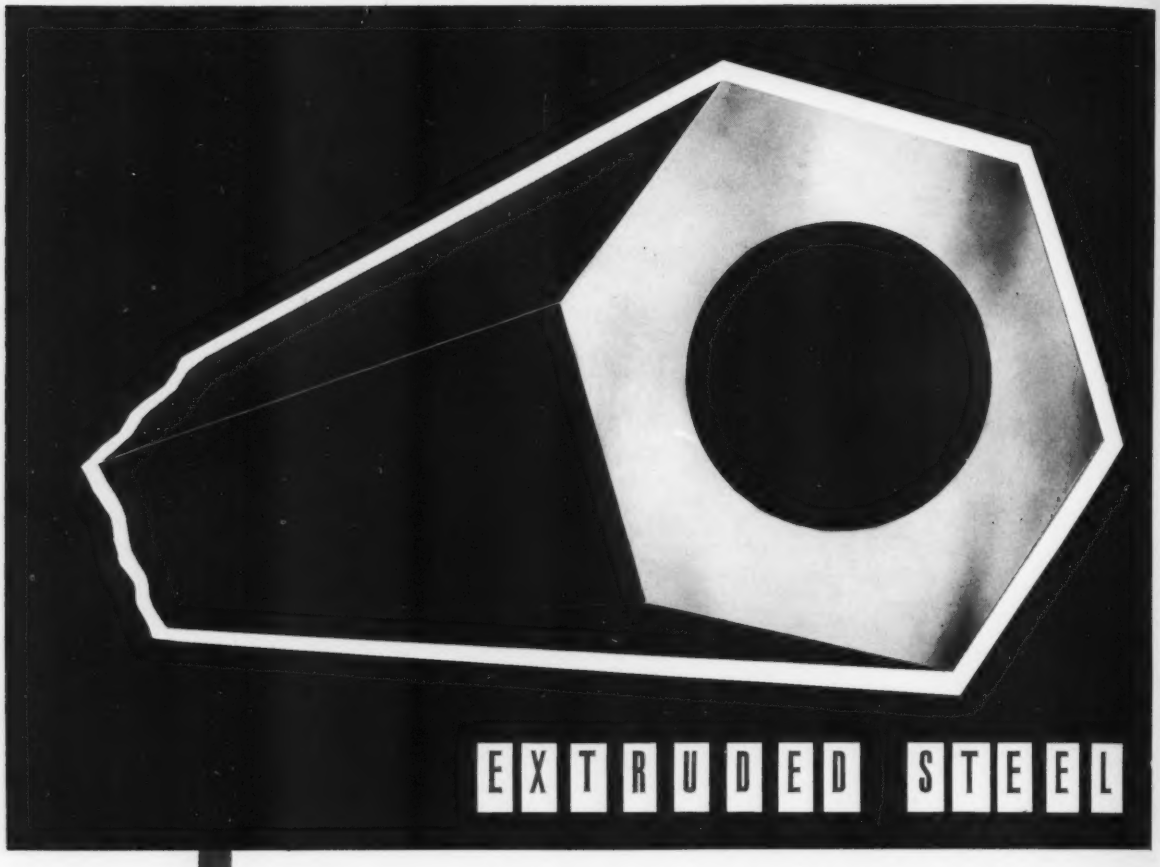
Engineering Materials and Design

DECEMBER 1968
TWO SHILLINGS AND SIXPENCE

Corrosion of Metals

Page 742

EMD 4122 for further information



SECTIONS

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Engineering Materials and Design

★ *The Magazine for Engineering Designers*

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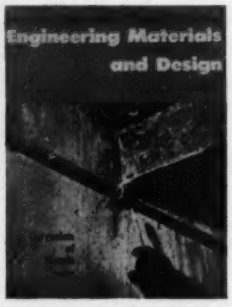

COVER: Corrosive atmospheres generated in the coke oven areas of a steel mill will destroy any type of ordinary metal electrical conduit, such as that shown above. Republic Steel Corp. now use plastics-coated metallic tubing, which has shown practically no deterioration in the first eighteen months of use.

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ISSUE AT A GLANCE

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CORROSION OF METALS **742**
Prediction of, and protection against, all types of corrosion.
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Résumés

FABRICATION ET APPLICATION DES PORTÉES PNEUMATIQUES PRESSURISÉES EXTÉRIEUREMENT

par H. L. Wunsch page 748

L'auteur traite d'abord des principes généraux et des propriétés des portées d'arbre pneumatiques ; il décrit, ensuite, brièvement, les travaux expérimentaux entrepris pour obtenir des renseignements qui permettront de construire un type spécial de portée à butée plate. Dans la dernière section de son article, il examine quelques applications typiques des portées pneumatiques.

CORROSION DES MÉTAUX

par H. D. Mallon page 742

L'article étudie les principes de la lutte contre la corrosion, les divers types de mécanismes de corrosion et les moyens de s'en protéger: choix des matériaux, méthodes de fabrication, revêtements, protection cathodique et inhibiteurs.

SÉCURITÉ DES MACHINES

par V. A. Broadhurst page 768

Après avoir souligné la responsabilité du bureau d'étude dans le domaine de la sécurité des machines et énuméré 25 éléments dangereux dans les machines, l'auteur étudie les effets de l'accroissement de la mécanisation et fournit des exemples typiques de machines sûres et de machines dangereuses.

MOTEURS DIESEL JUSQU'A 300 CV : 2ÈME PARTIE

page 758

Deuxième et dernière partie d'une étude complète donnant les caractéristiques et fournissant des tableaux de données concernant les moteurs Diesel construits dans le Royaume-Uni.

Kurzreferate

KONSTRUKTION UND ANWENDUNGEN VON ÄUSSERLICH UNTER DRUCK GESETZTEN LUFTLAGERN

von H. L. Wunsch Seite 748

Der Verfasser bespricht erst die allgemeinen Grundsätze und Eigenschaften von Luftlagern und beschreibt dann kurz Experimentalarbeiten, die zur Schaffung von Kunstruktionsdaten einer bestimmten Form eines flachen Polsterlagers durchgeführt wurden. Im letzten Abschnitt werden einige typische Anwendungen von Luftlagern besprochen.

METALLKORROSION

von H. D. Mallon Seite 742

Der Artikel bespricht die Grundsätze des Kampfes gegen Korrosion, die Arten und den Mechanismus von Korrosionsvorgängen, sowie auch Schutzmittel. Diese umfassen die Wahl des Materials und Konstruktions-, Beschichtungs-, Kathodenschutz- und Inhibitorenmethoden.

SICHERHEIT IM MASCHINENBAU

von V. A. Broadhurst Seite 768

Der Verfasser bespricht erst die Verantwortung des Maschinenkonstrukteurs mit Bezug auf die Sicherheit und führt dann fünfundzwanzig verschiedene gefährliche Maschinenteile an. Er bespricht dann die Einflüsse erhöhter Mechanisierung und gibt typische Beispiele sicherer und gefährlicher Konstruktionen.

DIESELMOTORE BIS ZU 300 BREMS-PS : TEIL 2

Seite 758

Schluss einer umfassenden Übersicht mit Konstruktionsdaten und Tabellen über Dieselmotore britischer Erzeugung.

Резюме

КОНСТРУКЦИЯ И ПРИМЕНЕНИЕ ПНЕВМАТИЧЕСКИХ ПОДШИПНИКОВ ПОД ВНЕШНИМ ДАВЛЕНИЕМ

Х. Л. Вунш стр. 748

В статье рассматриваются в первую очередь общие принципы и свойства пневматических подшипников. Затем вкратце описывается экспериментальная работа, проведенная для установления данных конструкции для определенного вида подшипника на плоской подкладке. В заключение обсуждаются некоторые характерные виды применения пневматических подшипников.

КОРРОЗИЯ МЕТАЛЛОВ

Х. Д. Маллен стр. 742

Статья обсуждает принципы рассмотрения проблем коррозии, типы и механику коррозийных процессов и виды охраны от коррозии — включая выбор материалов и методы строительства, облицовки, катодного прикрытия и ингибиторы.

СООБРАЖЕНИЯ БЕЗОПАСНОСТИ ПРИ КОНСТРУКЦИИ МАШИН

В. А. Бродхерст стр. 768

Подчеркнув ответственность конструктора за безопасность машин и перечислив 25 опасных частей машин, автор статьи обсуждает влияние роста механизации, приводя характерные примеры безопасных и опасных видов конструкции.

ДИЗЕЛЬНЫЕ ДВИГАТЕЛИ ДО 300 Л.С. — ЧАСТЬ 2АЯ

стр. 758

Заключительная часть всеобъемлющего обзора с деталями конструкции и табулированными данными касающимися дизельных двигателей, производимых в Соединенном Королевстве.

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Rubber Technology

TO A DESIGNER with an eye to future developments, one of the interesting papers given at the International Synthetic Rubber Symposium was that dealing with elastomers for advanced flight vehicles. The speaker said it was no secret that materials research had not kept pace with design, and the immediate goal was to close this gap and provide for future elastomer requirements. The ideal elastomer in this context would be radiation resistant with a temperature stability in the range 245-540 deg. C. It would stand up to vacuum, protect against acoustics and vibration, have extreme chemical resistance, and be stable for long periods of underground storage. The ideal maximum working temperature would be 430 deg. C., but no polymer approached this ideal. The nearest in the temperature range was p.t.f.e. at 250 deg. C., followed by vinylidene fluoride-hexafluoropropylene at 250 deg. C. and silicone at 230 deg. C., then nitriles at 140 deg. C. and natural rubber at 100 deg. C., but in all these elastomers other desirable properties were lacking. While work was progressing, particularly in testing and experimentation with rubber seals for hydraulic systems of missiles and rockets, only partial answers were yet available to the problems involved. Tensile strength, hardness and elasticity were correlated with the life of a seal; there were direct relations between temperature characteristics and sealing ability. In reciprocating seal tests in hydraulic oil, for example, surface finish was important. If too smooth, the seal would spall; if too rough, it would wear through.

In comparing tensile strengths at high temperatures, it was shown that butadiene-methyl methacrylates were best with a tensile strength of 1040 p.s.i. at 200 deg. F. These were followed, at the same temperature, by silicones at 650 p.s.i. and Viton at 330 p.s.i. It was, however, necessary to improve the ageing characteristics of the methyl methacrylate polymers. For use in fuel systems at high temperatures, the best fuel-resistant rubbers tested in a jet fuel of the kerosene type at 200 deg. C. for 70 hours at 250 p.s.i. were fluorinated elastomers such as Viton A and Viton B.

Chlorinated and fluorine polymers, silicone, butyl and Buna compounds did not approach the upper temperature limits required, and it was necessary to uplift the polymer characteristics, although some promising high temperature polymers with fuel resistance were being developed. The best of these were the polyamidines, which at 450 deg. C. retained rubber-like characteristics.

Improvements in the manufacture of nitrile rubbers, leading to superior performances was the theme of another paper. Although always distinguished by their outstanding resistance to petrol, lubricating oil and many organic solvents, and by resistance to heat, better abrasion and ageing than natural rubber, the nitriles today showed an improvement in all these characteristics.

Discussion showed that new synthetic rubbers were possible by using controlled structure polybutadienes, and of these the most important commercially was cis-1, 4 polybutadiene. In general, "cis-4," as it was familiarly called had an abrasion resistance 26 per cent superior to that of natural rubbers, and better low temperature characteristics. In the U.S.A., it had been suggested for tyres for winter driving, and it was thought that tyres of this material might be tailor-made to overcome particular hazards.

A similar approach was seen in the associated rubbers based on polyisoprene. In this case the Shell Chemical Co. planned to produce them shortly on a commercial scale. They claimed that there was striking similarity between polyisoprene and Hevea, although the end product might contain slightly different properties. These rubbers would be available for tyre and mechanical applications throughout industry. A man made "natural" rubber provided commercial rubbers at controlled prices, and removed the disadvantages of overseas sources of raw rubber.

The Commercial Motor Show

HIGHER SPEEDS AND HEAVIER LOADS on commercial vehicles have caused a corresponding increase in the demands on brakes. Where a vehicle is coasting for long periods the continued use of the brakes is uneconomical, therefore an alternate method of controlling the speed of the vehicle is of considerable interest.

The Thompson Retarder (Lockheed Hydraulic Brake Co., Ltd.) is a device which operates on a principle similar to that used in a fluid coupling, except that the drive to the wheels remains mechanically positive. The retarder, which is usually fitted between the gearbox and the rear axle, absorbs the energy of the roadwheels by agitating the fluid which it contains. The heat thus generated is dissipated through a radiator or heat exchanger.

In order to control the power absorption of the retarder, it is necessary to have a loading cylinder in the circuit between the retarder and the heat exchanger. This loading cylinder stores the fluid ordinarily used by the retarder during periods when absorption of energy is not required. When retardation is required, the driver actuates a hand control valve within the cab which, through the use of compressed air, forces the fluid stored within the loading cylinder into the retarder circuit.

By varying the amount of air pressure used to force fluid into the retarder system, a balance is obtained between the loading cylinder and the retarding system. Should the retarder tend to absorb more power than the setting of the hand valve permits, the retarder pumping pressure would then exceed the air pressure, forcing fluid back into the loading cylinder. Thus, by varying the control air pressure, the operator of a vehicle may vary the degree of retardation obtained from the retarder from zero to its maximum capacity for any particular vehicle speed.

A new self-locating unlubricated bearing assembly for high and low speed applications was shown by the Mintex Division of British Belting and Asbestos Ltd. Designed primarily for spring shackles, the bearing assembly consists of a centre convoluted pin and a pair of semi-circular half shells, the gap between them being filled by a bearing material so disposed that a thin surface of p.t.f.e. is in contact with the convoluted pin, thus forming a bearing surface. The design is such that the pin is an appreciable interference fit within the bearing material which is bonded to the half shells during manufacture. With this design, the elastic properties of the material and the interference fit will take up a normal amount of wear, and the surface is kept free from any contamination.

Sophisticated electrical systems for commercial vehicles are being introduced by the use of transistors in converters for fluorescent lighting (C.A.V.) in coaches, and by silicon diode rectifiers in the a.c. alternators introduced by Joseph Lucas Ltd. Also of interest are the battery-powered pump units for discharging liquid cargo from tanks, thus making the vehicle independent of outside facilities and enabling the unit to be sited independent of any mechanical drive from the engine.

PICTURE NEWS
IN THE WORLD OF MATERIALS & DESIGN

VISIBLE TYRE SQUEAL

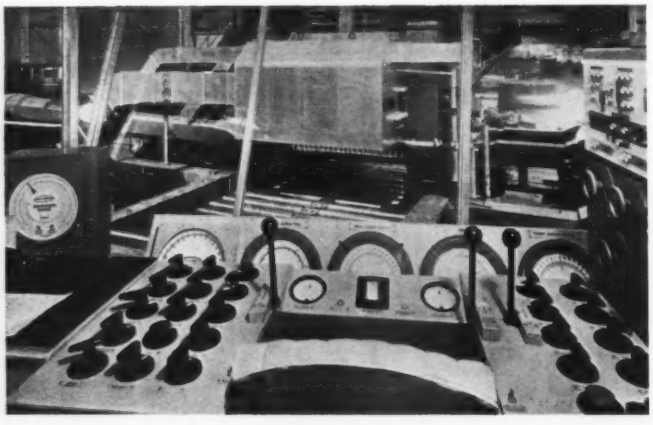
On the right is a three times enlargement of part of a scratched mirror pattern made by an outside front tyre cornering at 8½ deg. slip angle and 12 m.p.h. These scratches (photographed at the B.F. Goodrich Research Center, Ohio) show the vibratory movements which give rise to the sound recognized as squeal.

ADHESIVE FOR METAL-STAMPING DIE

Neoprene ejector springs are shown being bonded to metal and wooden die base plates with Eastman 910 quick-setting adhesive, which has proved capable of withstanding up to 40 tons pressure and the production of 250,000 stampings from one die without failure.

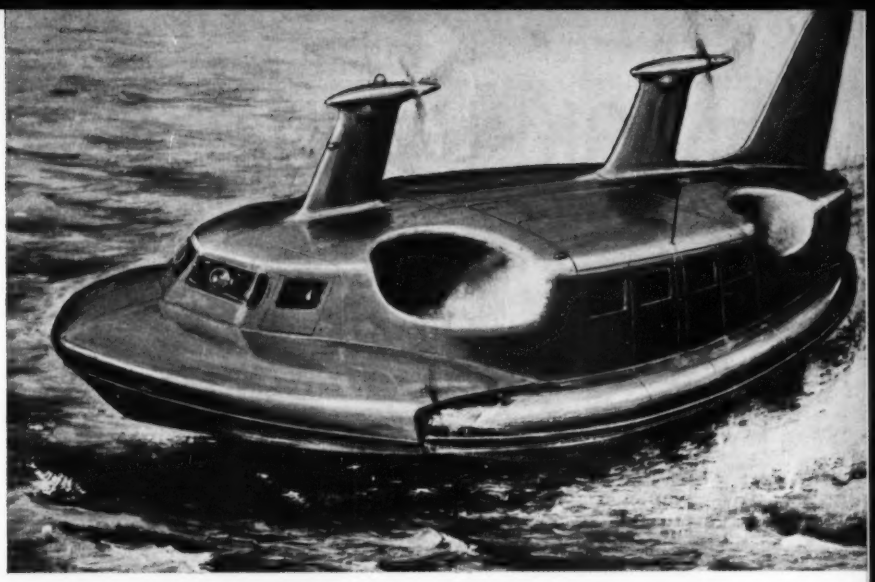
BRAKE LINING RESEARCH

The coach of the Ferodo test fleet has just returned from a fortnight's Alpine braking research. Drum temperatures were obtained by inserting thermocouples close to the centre of the braking path and feeding the voltage output via slip rings and silver graphite brushes to indicating meters.



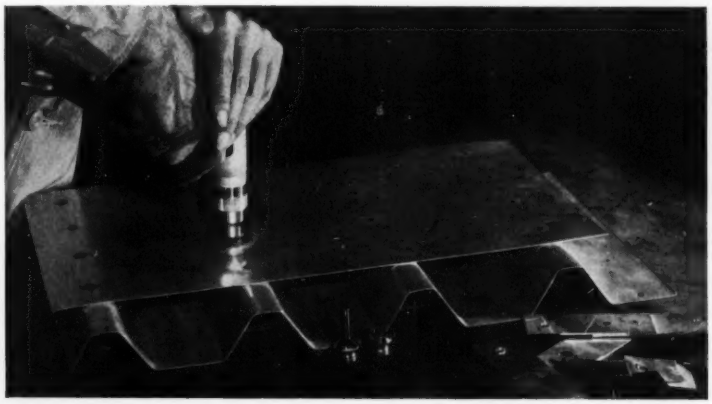
ERGONOMIC DESIGN

View of the controls of the biggest aluminium rolling mill in Europe, at the Rogerstone works of Alcan Industries Ltd. Note the wide field of vision and careful layout of instruments.



PROGRESS IN CUSHION CRAFT

Artist's impression of the Blackburn-powered SRN.2 hovercraft. The bow has been designed primarily for over-water operation, but the SRN.2 will also have considerable potential as an over-land vehicle.

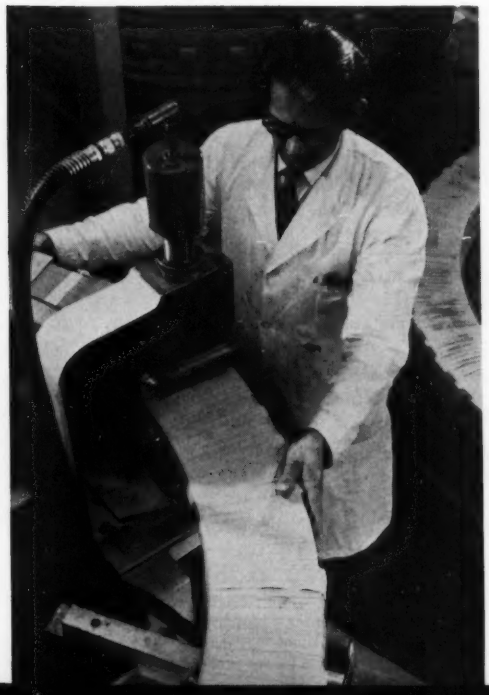


NEW WELDING TECHNIQUE

A prototype argon-arc spot-welding torch introduced by British Oxygen Co. Ltd. is seen here being used to weld aluminium. Access to only one side of the joint is needed, and spot welds can be made with one hand and by semi-skilled labour.

PLASTICS FOR SAFETY

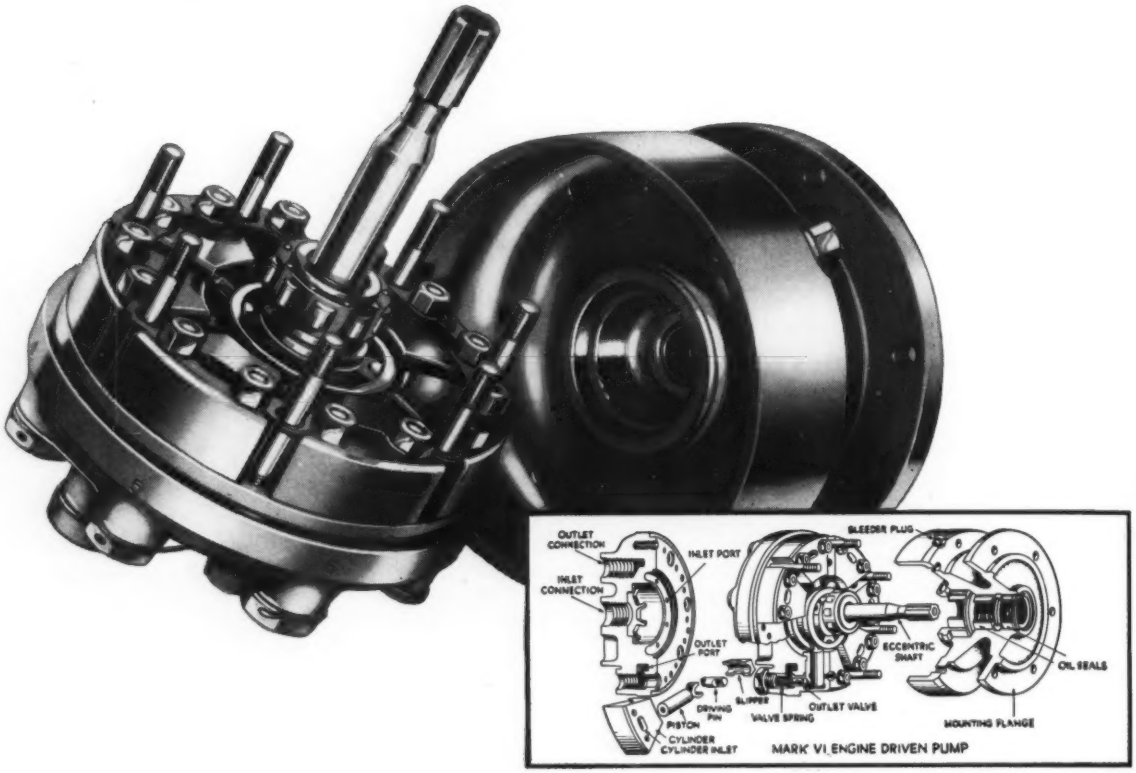
This floor polisher by Ladybird Appliances Ltd. is fitted with a housing moulded in Rigidex high density polyethylene, which is said to be virtually unbreakable and electrically safe.



MANUFACTURE OF TRANSFORMER COIL

Castellations are shown being cut on an interleaved disc coil at the new English Electric Transformer Works, at Stafford. These coils give high inter-turn capacity and reduced voltage stress under impulse conditions.

NICKEL ALLOY STEELS



ensure reliability in reciprocating units

Lockheed hydraulic pumps, made by the Automotive Products Company Ltd., Leamington, have a world-wide reputation for reliability in the aircraft industry. They are used to actuate flying controls, landing flaps, wheel brakes and undercarriages. Constructional materials are an important factor in achieving reliability in the normal 1000-hour period of operation during which, running at 3000 r.p.m., the plunger operates 174,000,000 times. To withstand the wear associated with reciprocating units, the three per cent nickel case-hardening steel 4S15 (En33) is specified for the cylinders.

TYPICAL CORE MECHANICAL PROPERTIES OF

EN33

ARE GIVEN BELOW:

SIZE	HEAT TREATMENT	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
1⅛" dia.	Oil quenched 860°C. Water quenched 770°C.	56·3	21·5	83
3" dia.	Oil quenched 860°C. Water quenched 760°C.	47·2	20	92

The benefits to be gained from the more highly alloyed case-hardening nickel steels, such as EN 33; EN 34; EN 36 and EN 39 include ease of heat-treatment, minimisation of processing distortion, and general reliability.

Please send for our publications entitled, 'The Mechanical Properties of Nickel Alloy Steels' and 'The Case Hardening of Nickel Alloy Steels'

MOND NICKEL

THE MOND NICKEL COMPANY LIMITED, THAMES HOUSE, MILLBANK, LONDON, SW1

TGA 21/21

Glass-Metal Composites

The Owens-Corning Fiberglas Corp. has recently been studying high temperature glass fibres. It is well known that compositions in the $SiO_2 - Al_2O_3 - MgO$ ternary, the $SiO_2 - Al_2O_3 - CaO$ ternary, and the $SiO_2 - Al_2O_3 - MgO - CaO$ quartenary systems offer a fertile field for fibres with exceptional high temperature strengths. Relying on glass forming knowledge gained in earlier studies, four glasses from the CaO ternary system were studied along with two glasses from the quaternary system and four glasses from the MgO ternary system. While most of the glasses, bare and aluminum coated, showed an improvement in tensile strength compared to E glass, the MgO ternary system offered the most promise.

This glass was formed at over 1,700 deg. C., and had an average tensile strength in the uncoated condition of 635,000 p.s.i., and a tensile strength of 178,000 p.s.i. coated with aluminum, roughly 50,000 p.s.i. greater than the tensile strength of aluminum-coated E glass fibres.

Originally it was thought that aluminum coatings applied to high temperature fibres at forming would serve to eliminate those glasses particularly susceptible to damage by reactive metals such as zirconium and titanium. Also, the coating step was thought to be a means for indicating those glasses which might lose strength rapidly at or above 650 deg. C. It was found, however, that even the more refractory fibres were not immune from attack by molten aluminum.

An experiment was initiated to determine if aluminum-coated high temperature fibres showing higher strengths than E glass aluminum-coated fibres would yield stronger glass-aluminum composites. Vacuum injection cast and hot pressed composites were made embodying one glass from each of the three composition fields. The tensile strengths of the composites were measured at room temperature, 260, 370 and 540 deg. C. The results did not differ significantly from those obtained previously for E glass aluminum composites.

Strong and fairly coherent green composites of crystalline fibres and stainless steel powder were made by hot pressing at 540 deg. C. and 25 t.s.i. Sintering was attempted with some success by heating pieces of the green compact for several hours at 980-1090 deg. C. while embedded in a protective mixture of powdered alumina and graphite. A considerable degree of sintering occurred with only minor oxidation from air entrapped in the sample. The results, while merely preliminary, indicate that fabrication of composites by these or similar methods is possible. Three methods of making green compacts are under study, and equipment is being designed for testing them.

The first method will be hot pressing, which is a modified powder metallurgy technique. The second method is slip casting, which has been recently developed for metals but is an old system for forming ceramic materials. The third method is low-temperature low pressure extrusion, which again is not a metallurgical but a ceramic technique.

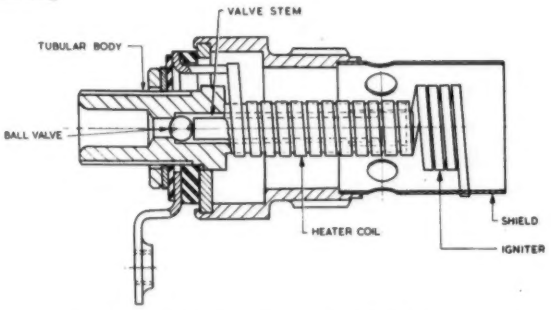
The Motor Show

THE EMPHASIS AT THIS YEAR'S MOTOR SHOW is on design sophistication rather than new achievements. For instance the a.c. alternator is now widely available, and many manufacturers are fitting it as standard. The new Dodge Lancer compact introduced by Chrysler International incorporates a 35-amp. three-phase alternator with full wave silicon diode rectification. A similar system was introduced last year on their Valiant.

Stainless steel, for example the door handles of the Simca Aronde, and light alloys are being increasingly used. Pleasing and useful variations of plastics upholstery are also to be noted, sealing materials being carefully selected to suit a specific application. Self-lubricating plastics bearings are finding increased uses.

The NSU power unit embodies several unusual design features, the chief of which is the eccentric connecting links used for driving the overhead camshaft. Although this design feature is not new to the current engine, it is nevertheless ingenious, and worth studying.

The Hydrosteer power-assisted steering box for the Rover 3-litre is an example of a fully integrated design. The steering arm is actuated by a peg riding in a spiral groove in what is in effect a continuation of the steering column. The arm is power assisted by an annular-type piston shrouding this extension shaft, the hydraulic fluid from the pump being controlled by a valve sensed by the resistance of the road wheels to turning.



Showing the internal-construction of the C.A.V. Thermostart.

The new Vauxhall Hydra-Matic automatic transmission uses a large number of aluminium die-castings, and employs two epicyclic gear trains and a fluid coupling incorporating a torque multiplier. The 2.6-litre engine has exhaust valves of composite construction, in which a wear-resistant steel stem is welded to a heat-resistant steel head. Tin-plated aluminium alloy pistons are used, the top piston ring being chromium plated.

The C.A.V. Thermostart (see diagram) is an interesting auxiliary for easy starting of diesel engines under extreme low temperature conditions. The unit is permanently fitted in the air inlet manifold, and is supplied with fuel oil which when burnt heats the incoming air to the engine. Engine starts at 0 deg. F. have been obtained, with considerably reduced strain on the batteries. A co-axial starter by the same company has been designed so that the starter pinion is moved axially into engagement with the engine flywheel ring, full torque for turning the flywheel being applied when the pinion is in full engagement.

The Cornette carburettor and manifold heater can be fitted to any car, and is designed to ensure easy starting of petrol engines and to prevent ice formation within the carburettor under extreme low temperature conditions.

Ribbon cables have been developed by Rists' Wires and Cables Ltd. to facilitate wiring in confined spaces, the p.v.c. insulation being available in an almost unlimited number of colours.

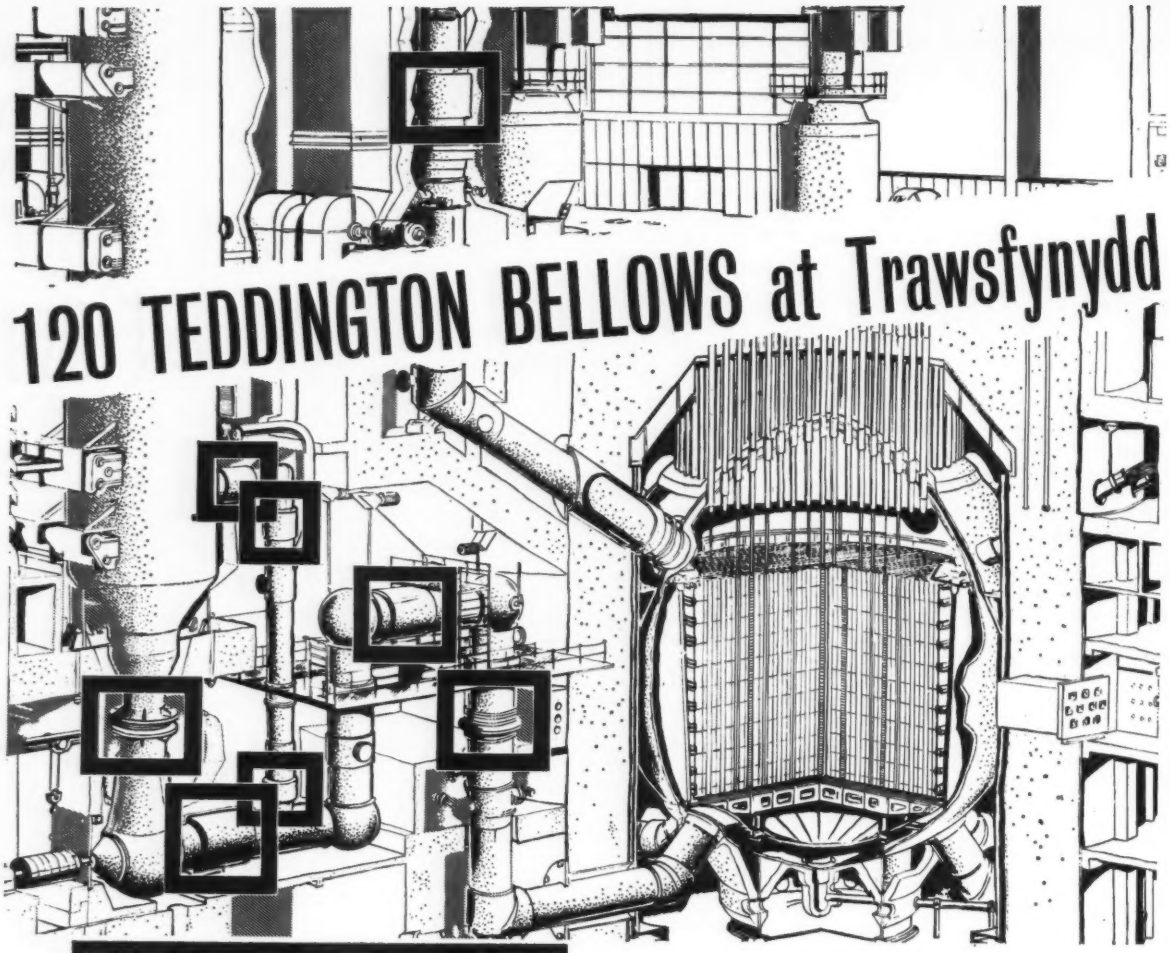
Vitreous Enamelled Aluminium

ONE OF THE LATEST and most interesting developments in the vitreous enamel industry is the enamelling of aluminium. During the past two years this process has become established commercially in the U.K., and a considerable growth in the use of vitreous enamelled aluminium is foreseen in the future. As part of its programme in promoting the use of vitreous enamel and maintaining high standards for the industry, the Vitreous Enamel Development Council has just published a tentative commercial specification for vitreous enamelled aluminium for architectural applications. This follows up the V.E.D.C's. recommended standards and general specification for vitreous enamel now included in the brochure "Vitreous Enamel in Architecture."

Since aluminium melts at 650 deg. C., which is lower than the firing temperature of steel enamels, new frits (the crystalline substance from which vitreous enamel is made) have been developed, thus making possible the process of enamelling aluminium.

Vitreous enamelled panels have been used on buildings in the U.S.A. for over ten years. During 1957, 5,000,000 sq. ft. of aluminium was coated with vitreous enamel, and the figure forecast for 1961 is in the region of 23,000,000 sq. ft.

Vitreous enamel enhances the good features of aluminium. It adds colour in an almost unlimited range, it maintains its original appearance over long periods, and it is simple to clean. It is also light and easy to handle, and can be sheared or cut with practically no serration of the edges.



120 TEDDINGTON BELLOWS at Trawsfynydd

By courtesy of 'NUCLEAR POWER'

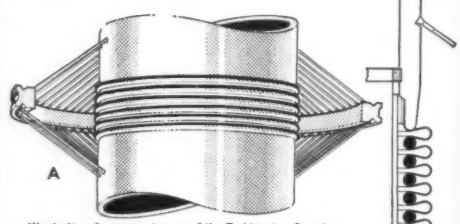


Illustration A represents one of the Teddington Stainless Steel Bellows supplied to Trawsfynydd with a novel form of restraint designed by Richardsons, Westgarth & Co. Ltd. (a member of Atomic Power Constructions Ltd.). This avoids the use of highly stressed hinge pins and permits a complete gimbal movement.

Illustration B indicates a section of Teddington Bellows, showing the restraining rings for extra strength which are a feature of this bellows design.

NO LESS THAN 84 BELLOWS 66″ diameter and 36 BELLOWS 42″ diameter, all of butt-welded stainless steel manufacture, are being fitted at Trawsfynydd to take up movement in the CO_2 cooling gas ducts.

Teddington secured this order only after many exhaustive tests including an accelerated life test equivalent to 20 years full operation. In addition, the larger size bellows were subjected to over-pressure tests of 1580 p.s.i.g. without developing a leak. Wherever pipe-work is subjected to vibration and movement in any direction owing to conditions of temperature and pressure, a Teddington bellows with a suitable end fitting will solve the problem. Write for full details of our range.

TEDDINGTON AIRCRAFT CONTROLS LIMITED

(INDUSTRIAL BELLOWS DIVISION),

AMMANFORD, CARMS.

Made under Licence from the Solar Aircraft Co. California, U.S.A.

Metal Fatigue Tests Yield Early Discovery

STEEL SUBJECTED FOR A SHORT PERIOD to extreme stresses reacts in a manner diametrically opposed to that of some light alloys. This discovery was announced by Dr. Hempel of Germany at a meeting of the Working Party on Fatigue Failure in Metals, organised by the European Productivity Agency of the O.E.E.C. This Working Party was set up because a series of failures — among them being the accidents to certain airliners — revealed that too little was known about the nature and causes of fatigue in metals. It was decided that at least 5,000 test-pieces must be tested to destruction, particular emphasis being laid on the effects of variation in the degree of stress applied. When one considers the variation in stress in a car's engine between idling, accelerating and fast cruising, it is obvious that this is what happens to most metal parts in daily use.

To attempt to carry out this work in a single laboratory, or even a single country, would take far too long, and this is one of the instances where international co-operation, co-ordinated by a central organisation, can be very useful. In fact, the tests are being carried out in nine European countries, in the U.S.A., and in Canada.

So far some 500 test-pieces have been used, chiefly with the idea of establishing whether the working methods and the stresses agreed on in advance were suitable. They have proved to be so, and work is now about to begin on the main batch of 5,000 test-pieces. They will be tested for varying periods at four different stresses, known for convenience as S1, S2, S3 and S4. The value of S4 used by Dr. Hempel was 70 kg./sq. mm.

Although these preliminary tests were not expected to yield any results, it rapidly became apparent that steel subjected to stress of this severity for even a short time subsequently cracked up very fast under much lower stresses—S1 or S2. The effect on various light alloys, however, was to harden and strengthen them so that they subsequently stood up better to prolonged periods of moderate stress than they did when not subject to an initial period of high stress.

As M. Crussard, of the Institut de Recherche de la Sidérurgie, Chairman of the Working Party, pointed out, it is extremely heartening to have even a partial result at this early stage, and one which obviously gives a useful lead for further experiments.

The main body of tests, spread out over eleven countries, will be completed within a year, and the results should go a long way towards making machines safer and more durable.

Manufacture of Delrin in Europe

IT IS STILL LESS THAN TWELVE MONTHS since the introduction in the U.S.A. of a new man-made engineering material — Delrin acetal resin. It is now announced that the Du Pont Co. are to build a plant in Dordrecht (Netherlands) where Delrin will be produced for use by the European market.

THE JANUARY ISSUE

of *Engineering Materials and Design* will include the following main features:

Cellular Plastics
Giving the physical properties and applications of commercially important materials.

Diesel Engines up to 300 b.h.p.: Part 3
Design features and tabulated data—concluding section.

Information for Engineers
Description of technical information services available in the U.K.

Engineering Applications of Isotopes
Abstracts from conference Papers on the use of tracers.

These views of a new self-seating tap show four parts, formerly of brass, now made of Delrin acetal resin.

Delrin is a tough, rigid thermoplastics, developed primarily for use in fields now dominated by die-cast metals. Over 80 per cent of its potential applications involve replacement of metals, particularly die-casting alloys. It is a highly crystalline, high-melting polymer, known chemically as a linear acetal resin, or a polyoxymethylene. Its dense crystalline structure accounts for many of its key properties—strength and stiffness, good high temperature performance, solvent resistance. It is the first plastics with strength properties approaching those of the non-ferrous metals, and in a real sense is metal-like, in that it will do many jobs hitherto performed only by metals.

The outstanding feature of the resin is its unique combination of properties. It is extremely rigid without being brittle, and is both tough and resilient, much like spring steel. Perhaps its most unusual feature is that it retains these properties under adverse conditions of temperature and humidity, during an extended time under stress, and during exposure to most solvents. Though hefty by comparison to most other plastics, it is lighter than any of the die-casting alloys: 80 per cent lighter than zinc, 45 per cent lighter than aluminium, and over 20 per cent lighter than magnesium.

Limits of Dimensional Variation in Glass

THE INCREASING USE OF GLASS in engineering has drawn attention to the need for defining suitable dimensional limits consistent with the aim of the designer and the accuracy of equipment in current use. The high degree of dimensional variation which characterises most forms of glassware presents considerable difficulty to the designer when glass is used in technical applications. The contrast between glass and other raw materials is a striking one, since most of the materials used in engineering or technical fields can be machined or fabricated to limits of accuracy of 0.001 in., or even 0.0001 in. where necessary, whereas glass in the form of tubing, bulbs or pressings cannot usually be made to limits of accuracy better than 0.01 in., except by special manufacturing techniques which are inherently expensive.

While this dimensional variation is the root of many problems arising between producer and customer in the glass industry, the recent paper "Method of Calculating Limits of Dimensional Variation," by Morrison and Symons, presented to the Society of Glass Technology, is worthy of serious consideration by designers in other industries where consistent accuracy is not always possible, and where the theory of probability is involved.

Inserting a manifold core in a die, at Qualcast Ferrous Diecast Division.

Die Casting in Iron

Although the process itself is not new, die casting is usually associated with non-ferrous products, and its use for cast iron components is not widely known. Its value lies in the economy which can be achieved on large volume production, and the consistency of the products. Qualcast Ltd. have in their Derby works the only machine in the U.K. for producing die cast components in cast iron, and over 30,000,000 castings a year are at present made, the reject rate associated with this process being only 0.38 per cent of the total. The process is entirely automatic, each machine carrying twelve die sets on a circular table, which in a single revolution or cycle causes the dies to open and eject the casting, coats the faces of the die with soot from an acetylene burner to prevent freezing of the metal, receives cores where required, and closes the dies for the pour from a ladle. Each half of the die is made from cast iron and is air cooled, the cycle being timed to ensure that the period from pouring to ejection is sufficient to enable solidification (which may be initially only of skin thickness) to take place.

Although the dies have only a limited life, varying between a component production of a few hundreds to a few thousands, the process can still be economical because the finished dimensional tolerances associated with the dies are equivalent to those obtained with sand mouldings. Thus the dies can be produced at a relatively low cost.

Although many different cast iron specifications are used in the sand foundry, only one grade (BS 1452, grade 12) is suitable for die casting. In addition to the periodic check on the composition of the metal, components are taken from the machine at regular intervals for tests on their mechanical properties, and for a crack detection process. From the designer's angle, the criteria used for designing sand-produced castings can be applied equally well to die castings, the choice between the two processes being entirely dependent upon the quantity allied to the shape and weight of the component. Output from the Qualcast foundry is largely taken up by the motor industry, typical components being manifolds, brake drums and hydraulic cylinders.

A recent Russian article describes the possibilities of steel die casting, althongh at the present time the demand in the U.K. for steel die castings is insufficient to warrant such a process. It is pointed out that not all types of steel are suitable for die casting, and that flaws are most likely to occur in steels having above 0.2 per cent carbon. The most suitable steels would appear to be the non-hardening types with a high degree of plasticity containing up to 0.15 per cent carbon. Certain steel alloys, for instance chrome-nickel austenitic steel, are also considered suitable. To eliminate flaws from shrinkage the casting material must be fed consistently, the feeder section and pouring gate requiring special attention. The ventilation of the mould-cavity is also important. It is regarded as essential that the process of die casting in steel include a vacuum technique for degassing.

International Congress on Metallic Corrosion

PLANS FOR THE FIRST INTERNATIONAL CONGRESS FOR METALLIC CORROSION have reached an advanced stage, and it is now possible to give a brief outline of the provisional programme.

The Congress will be opened on Monday afternoon, April 10, by the president, Sir Harry Melville, K.C.B. Plenary lectures will be given by the following eminent authorities in the field of metallic corrosion: Professor Y. M. Kolotyrkin (U.S.S.R.), Professor P. Lacombe (France), Professor H. H. Uhlig (U.S.A.) and Dr. U. R. Evans (U.K.).

The papers will be grouped under the following headings: High Temperature Oxidation; Atmospheric Corrosion; Underground Corrosion; Inhibitors; Electrochemical, Thermodynamic and Kinetic Studies; Laboratory Corrosion Testing and Experimental Methods; Protection by Metal Coatings; Protection by Non-metallic Coatings or by Chemical Treatment; Cathodic and Electrolytic Protection; Stress and Intergranular Corrosion; Corrosion Fatigue; Corrosion in Boilers and Heat Exchangers; Corrosion in the Atomic Energy Field, and Industrial and Service Experience.

In collaboration with the organisers of the Congress, the Science Museum (which is close to the lecture theatres) is arranging a Corrosion Exhibition, mainly of historic interest, which should prove attractive to delegates from overseas.

New Self-lubricating Material

Plastics are being used in ever widening applications for bearings and sliding parts, but many of these materials do not have sufficiently good lubricating properties to satisfy all requirements. P.t.f.e. has a very low coefficient of friction but it possesses other undesirable properties, particularly creep, which severely limits its use in engineering applications. In order to overcome this defect, p.t.f.e. is used as a thin film impregnated into the surface of porous bronze, but there is now news of a further development which employs p.t.f.e. in an all-plastics composite.

The new material, for which Provisional Patent cover has been taken out, is the result of work by a private inventor (Mr. P. E. Thomas) who claims to have combined the rigidity and stability of epoxy resins with the lubricating properties of p.t.f.e. The process consists of mixing up epoxy resin and solid lubricant such as graphite or molybdenum disulphide together with hardener, and taking it to the "B" state of cure, where it is solid but still capable of being remelted. This material is then ground up and mixed with p.t.f.e. powder in the unsintered condition. The mixture can then be extruded warm into rod, which at this stage is pliable and capable of being handled. The rod can then be calendered through rolls to any desired thickness from 0.005 in. upwards, after which it is finally cured in an oven.

The finished bearing material is homogeneous, and therefore bearings made from it can be machined in situ for final alignment. It is very light (density 1.91), and can be firmly bonded to metal backings, even aluminium, during the curing operation, after which bearings can be formed from the strip. This may open up possibilities for the material in aircraft and missile applications, where weight is specially significant. Dry lubricants also have expanding applications in the textile, food and atomic energy fields, where contamination by lubricants is inadmissable.

FOR FURTHER INFORMATION:—

Owens-Corning Fibreglas Corp., Newark, Ohio.

Vitreous Enamel Development Council, 28 Welbeck Street, London, W.1.

O.E.E.C., Information Division, Château de la Muette, 2 rue André-Pascal, Paris, XVIé.

Du Pont Co. (U.K.) Ltd., 76 Jermyn Street, London, S.W.1.

Society of Glass Technology, Thornton, Hallam Gate Road, Sheffield, 10.

Qualcast Ltd., Victory Road, Derby.

International Congress on Metallic Corrosion, 14 Belgrave Square, London, S.W.1.

Mr. P. E. Thomas, "Gay Thorns," Chalk Lane, Ashtead, Surrey.

TRIAL AND ERROR NO LONGER NON-U

ENGINEERING design can be by trial and error or by calculation, the latter being the way we are taught and the former the way we often practise! Scientific education includes the teaching of the "scientific method" and, as about 70 per cent of engineers are schooled on a scientific rather than a classics basis, it might be presumed that they are taught the logical process of assembling facts and figures before expounding a hypothesis or formulating a design.

Chemists are warned to avoid the temptation of trying all the bottles on the shelf one by one until the desired reaction takes place, and engineers are provided with formulæ to enable them to calculate with fine precision the strength of a bracket. It is not until they come face to face with the facts of life (such as shock loads, corrosion fatigue and queer environments) that the shortcomings of the scientific method become obvious when applied to engineering design. We sometimes wonder whether, even in scientific research, the method is used as widely as one might think, because the most eminent scientists appear to adopt a beautifully balanced blend of calculation, knowledge and intuition, the latter disguising, we suspect, a large measure of experience gained from the errors of trials.

Engineers are usually very anxious to publish the steps of a calculated method of approach, but will rarely admit that they had to build eight prototypes before final success was achieved. There seems to be a strong undercurrent of shame about having to admit that one does not know all the variables, and must resort to practical experiments in order to achieve success. It is time that this phoney shell was removed, and at last a large company has openly admitted that the most practical and economic way of designing large power transformers is by trial and error, using computers.

At a recent visit to the new transformer works of the English Electric Co., at Stafford, this design method was explained. The programme first assumes a typical value for several basic design constants, such as copper space factor, and ratio of total load loss to I^2R loss. These constants are used in fundamental equations which relate design characteristics to core flux density and overall winding dimensions. When solved, these equations provide a trial value for flux density and overall core and winding dimensions, and using these a detailed design is completed and all performance details calculated. The first design will probably not meet the required performance but, using simple formulæ, it will enable the basic constants to be modified and the process related to produce a second design. This is repeated as many times as is necessary until a satisfactory design is obtained. The programme is simple to use and requires no knowledge of computers on the part of the designer. The machine calculation takes about one minute before the completed design is punched out on cards, which are then transferred to a tabulating machine to enable the design to be translated into a form acceptable to the designer. Ten designs may be completely processed within half an hour, and the effect of new materials such as improved grades of steel or insulating materials may be readily assessed over a wide range of designs.

The computer has no design intuition, and can only carry out operations as instructed. Therefore, the designer need not feel that he is being made redundant, or that his importance is being undermined. On the contrary, the computer, if used intelligently, should augment the designer's brain, enabling him to achieve better designs and freeing him for creative effort. Furthermore, it enables him to employ trial and error methods as a sensible and honourable procedure.

The Editor

CORROSION OF METALS

It has been estimated that the annual cost of corrosion in the U.K. is £600 million,[1] £40 million of which goes to painting iron and steelwork.[2] Such losses obviously justify a major research effort on this problem

by H. D. MALLON, B.Sc., A.R.T.C., A.I.M.*

THE corrosion of metals stems fundamentally from the fact that engineering metals are used in a chemically metastable form. The stable conditions of these metals are the oxides, chlorides, sulphates and other salts. Given the necessary conditions and activation energy, the common metals revert to their more stable compounds. Two approaches to the problem can be made. First, knowing the extent and type of corrosion to be expected, components can be made thicker to allow for a reasonable life. Secondly, the corrosion reaction can be slowed down or stopped. In the second case, in addition to information about the amount and type of corrosion, the actual mechanism must be understood. The second approach is obviously the most satisfying, though not necessarily the most economic.

A scientific attack on the problem requires quantitative measurements of the corrosion reactions. This is not quite so simple as might appear at first sight. Measurement of loss in weight of samples is probably the most common measurement made, but if localised corrosion, such as pitting, occurs the figures will underestimate the danger of perforation of containers. Frequently it is necessary to use two or more different methods of measurement if a reliable opinion of corrosion resistance is to be formed. Another difficulty is the correlation of corrosion measurements with practical experience. Table 1 is a tentative effort in this direction but should be used cautiously, since a corrosion rate which is low for one purpose, such as a pump casing, may be considered high for another application, for example in bearings.

Table 1. Comparative corrosion rates—approximate values

	Very Low	Low	Moderate	High	Very High
In./year ...	0·0001	0·001	0·01	0·1	1·0
mgm./sq. dm./day ...	0·5	5	50	500	5,000
milliamp./sq. cm. ...	0·0002	0·002	0·02	0·2	2·0

Corrosion Mechanisms

It is convenient to consider corrosion mechanisms as falling under a number of different headings, although in fact there are no hard and fast boundaries. Three divisions are considered here, namely, high-temperature corrosion, atmospheric corrosion and immersion corrosion. Situations where overlapping occurs are frequent, the most obvious perhaps, being the exhaust system of a motor car.

HIGH-TEMPERATURE CORROSION—The use of metals at high temperatures has been limited mainly by the increase in oxidation and the fall in strength as the temperature rises. Plain carbon and low alloy steels are limited to temperatures of about 450 deg. C. by the scaling properties of the material, but modern alloys such as the Nimonics and Hastelloys have excellent oxidation resistance. With the latter it is generally their creep resistance which limits the working temperature.

The adherence and protective capacity of an oxide or

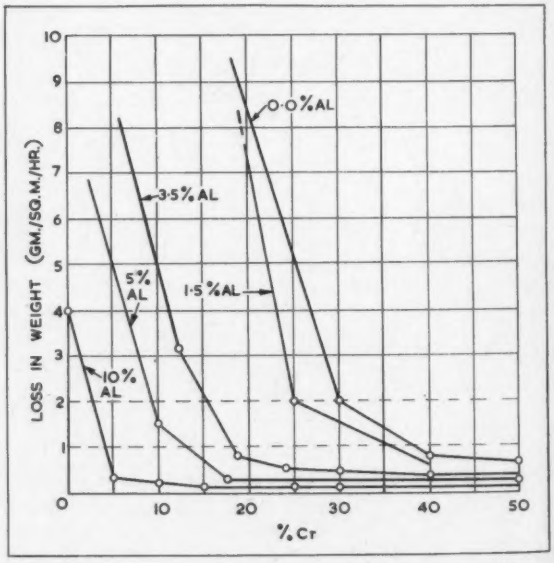


Fig. 1. Oxidation of Al-Fe alloys at 1,100 deg. C. (2,010 deg. F.) in air, as a function of chromium content. (Multiply by 240 to obtain mdd.) (W. E. Ruder, p. 668 in the *Corrosion Handbook* —John Wiley; Chapman & Hall, 1948.)

* *Metallurgy Branch, Royal Military College of Science, Shrivenham.*

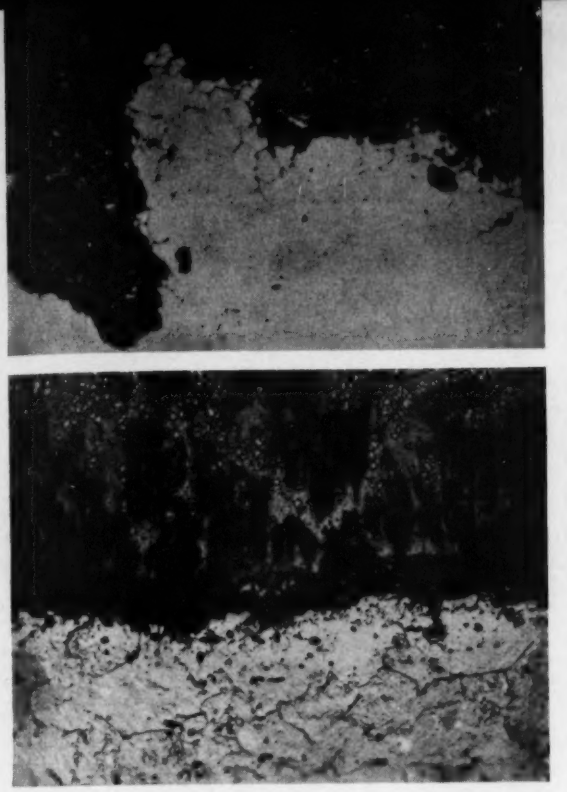


Fig. 2. Typical micrographs of oxide films formed by heating in air; (*above*) on austenitic stainless steel (protective), and (*below*) on mild steel (non-protective).

other surface film is difficult to assess from theoretical considerations, so that tests are essential. Nevertheless, much practical information of a general nature is available which assists in evaluation. Figs. 1 and 3 are typical examples Many factors contribute to the behaviour of oxide films. The mechanism of growth obviously plays an important part. There are three main types of oxide: those with a stoichiometric composition, such as aluminium oxide; secondly, oxides which are deficient in metal ions, where oxidation occurs mainly by diffusion of oxygen through the film to oxidise the metal surface; and thirdly, oxides deficient in oxygen ions where the metal diffuses through the oxide layer and oxidises at the free surface of the film. Cu_2O, CuO, ZrO_2 and TiO_2 appear to be oxides of the second type, while FeO and Fe_3O_4 appear to be of the third type. In the oxidation of Ni to NiO both mechanisms operate.[3] These diffusion mechanisms often lead to holes in the oxide film and at the metal/oxide interface. They obviously play a major part in determining adhesion. Fig. 2 shows typical micrographs of oxide films formed by heating in air. Changes in crystal structure of the oxide or of the underlying metal induce volume changes which can destroy adherence. The solubility of the oxide in the metal might be expected to assist keying of the oxide, but some of the highly protective oxides, such as Cr_2O_3, are virtually insoluble in their base metal. The relative coefficients of thermal expansion are obviously a factor in adhesion, and the wide difference between copper and its oxide probably accounts for the ease with which Cu_2O flakes off copper when quenched in water from the annealing temperature. The Pilling and Bedworth[4] ratio of volume of oxide to volume of metal from which it forms is not an infallible criterion for adhesion or protection.[5] Further factors complicate the problem still more. Thus, the oxides of some metals such as Mo and V are volatile and offer no protection. Other oxides, such as FeO and sulphides such as NiS, form eutectics with the base metal where the eutectic melts at temperatures much lower than the metal, and can give rise to embrittlement of the metal by grain boundary penetration if the metal is stressed. Eutectics can also form between impurities in the gaseous atmosphere, such as sulphides or V_2O_5, and the protective oxides, thus destroying the protection.

ATMOSPHERIC CORROSION—A useful and detailed classification of terrestrial atmospheres is given by Greathouse and Wessel.[6] Relative humidity seems to be one of the main controlling factors in this type of corrosion, but little factual information has been published. Iron and steels show little corrosion below 50 per cent relative humidity, slight corrosion up to 80 per cent R.H., and increasingly severe corrosion above this value. Fig. 4 illustrates this point. Magnesium, on the other hand, shows corrosion at humidities above 30 per cent and rapid tarnishing at 60 per cent R.H. Atmospheric pollution largely determines the rate of corrosion provided the R.H. is sufficiently high. Inert impurities such as silica dust can increase corrosion rates probably due to oxygen concentration cell effects. Soot deposits, although chemically inert, can form electrolytic cells, owing to the electrical conductivity and cathodic potential of carbon. Weak acids, such as sulphurous acid and carbon dioxide, increase rates of attack on steels and magnesium alloys, while copper alloys are sensitive to ammonia, small concentrations of which can cause stress corrosion cracking of cold-worked brass. Tolerance of atmospheric impurities depends to a large extent on good housekeeping. Frequent cleaning and polishing allows many alloys to be used in conditions likely to cause severe corrosion.

Positional effects are noticeable. Protected surfaces where moisture can collect, where evaporation is slow, and where the corrosion products are not washed away by rain, generally show more corrosion than exposed surfaces. High temperatures promote corrosion, provided the humidity is sufficiently high, while at temperatures below 0 deg. C. corrosion is negligible except in heated buildings and similar places where condensation takes place.

Records of extensive field tests for a very wide range of materials in different climatic conditions have been published both in the U.K. (Reports 1 to 6, Corrosion Committee, Iron and Steel Institute; and Reports of the British Non-Ferrous Metals Research Association, published by the Faraday Society), and in the U.S.A. by the American Society for Testing Materials (*Proc. Am. Soc. Testing Mat.*).

IMMERSION CORROSION—Electrochemistry[7] can provide explanations of the corrosion mechanisms of metals immersed in conducting solutions. Electrodes immersed in aqueous solutions develop a potential relative to the solution. The potentials developed by the chemical elements under standardised conditions of temperature, concentration and pressure enable the elements to be arranged in order of their Normal Electrode Potential. The Normal Electrode Potential of hydrogen is fixed arbitrarily as 0·000 volts. Galvanic series, such as that shown in Table 2, consist of common metals and alloys arranged in order of corrosivity as indicated by their anodic behaviour towards metals lower in the list. The anodic or corrosive metals appear at the top of the series, the cathodic or noble metals at the bottom, but the series is imprecise in its arrangement, although it reflects general experience. Interchange of a few places in the series is quite common with varying conditions of corrosion.

The behaviour of iron can be used to indicate briefly the general principles involved. Two main reactions take place when iron is immersed in aqueous solutions; namely, the hydrogen evolution reaction

$$\underset{\text{ions}}{2H^+} + \underset{\text{electrons}}{2e^-} = \underset{\text{gas}}{H_2}$$

and the oxygen absorption reaction

$$\underset{\text{soluble gas}}{O_2} + \underset{\text{water}}{2H_2O} + \underset{\text{electrons}}{4e^-} = \underset{\text{ions}}{4(OH)^-}$$

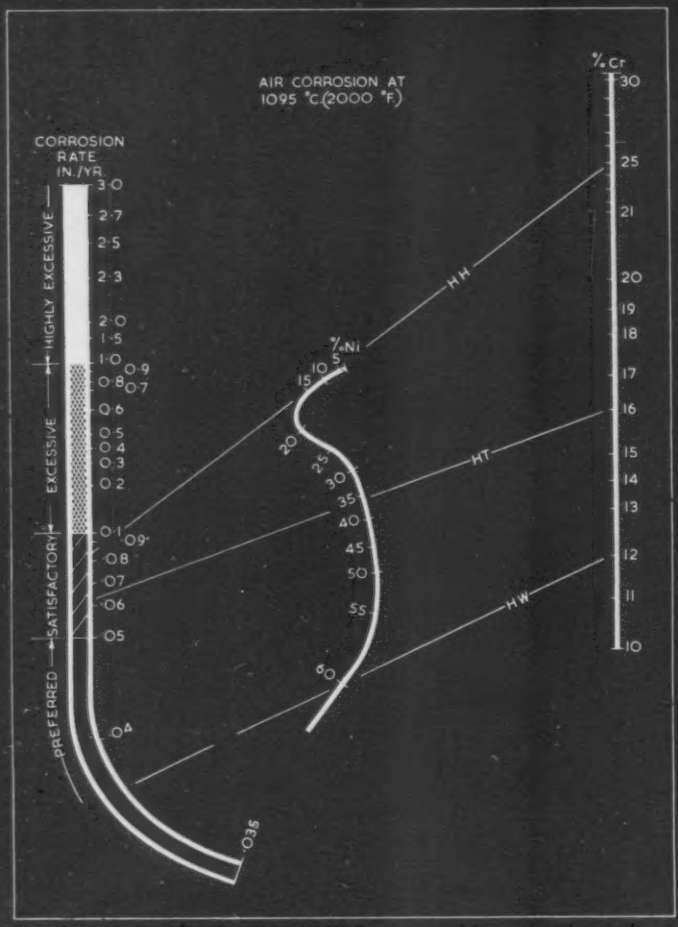


Fig. 3. Relationship between the Ni-Cr content of ferrous castings and air corrosion. (Courtesy of the Alloy Casting Institute.) (M. A. Hurter, p. 692 in the *Corrosion Handbook*.)

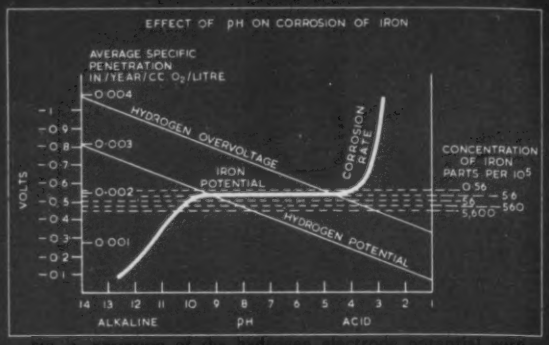


Fig. 4. Variation of the hydrogen electrode potential with pH (log. of the reciprocal of the hydrogen ion conc.).

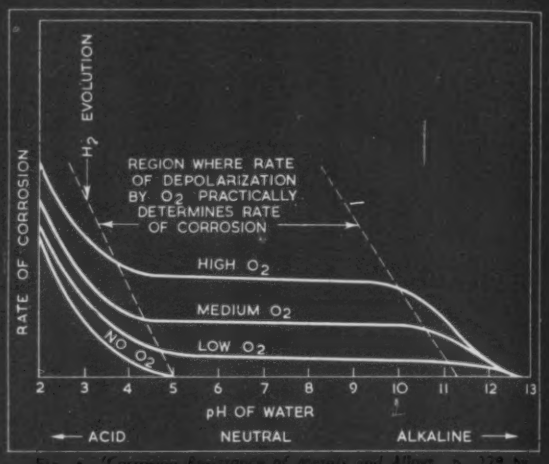


Fig. 5. (*Corrosion Resistance of Metals and Alloys*, p. 229, by McKay and Worthington—Reinhold—1936.)

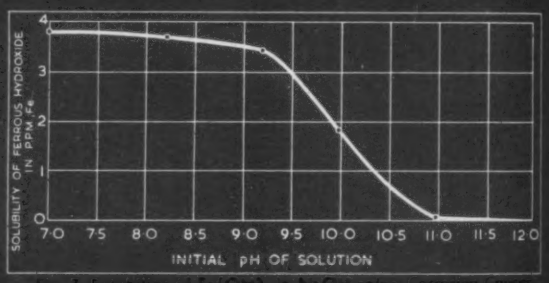


Fig. 7. Solubility of $Fe(OH)_2$ in NaOH solns. (*Corrosion Causes and Prevention*, Fig. 40, by Speller—McGraw-Hill, 1935.)

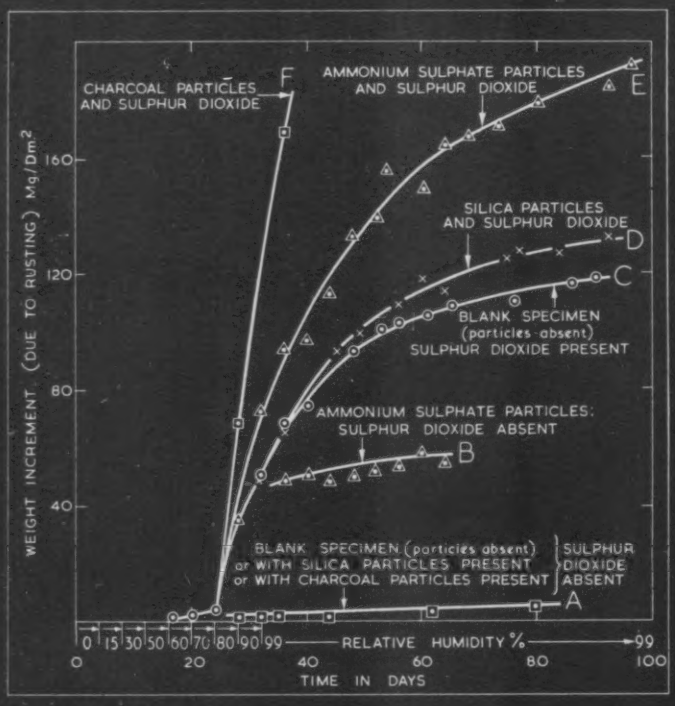

CHARCOAL PARTICLES AND SULPHUR DIOXIDE
AMMONIUM SULPHATE PARTICLES AND SULPHUR DIOXIDE
SILICA PARTICLES AND SULPHUR DIOXIDE
BLANK SPECIMEN (particles absent) SULPHUR DIOXIDE PRESENT
AMMONIUM SULPHATE PARTICLES: SULPHUR DIOXIDE ABSENT
BLANK SPECIMEN (particles absent) or WITH SILICA PARTICLES PRESENT or WITH CHARCOAL PARTICLES PRESENT
SULPHUR DIOXIDE ABSENT
WEIGHT INCREMENT (DUE TO RUSTING) Mg/Dm²
RELATIVE HUMIDITY %
TIME IN DAYS

Fig. 6. Breakdown of air-formed films on iron: promotion of rusting at critical humidity. ("The Corrosion of Metals in Air" by W. H. J. Vernon, in *Chemistry and Industry*, 62, p. 314, 1943.)

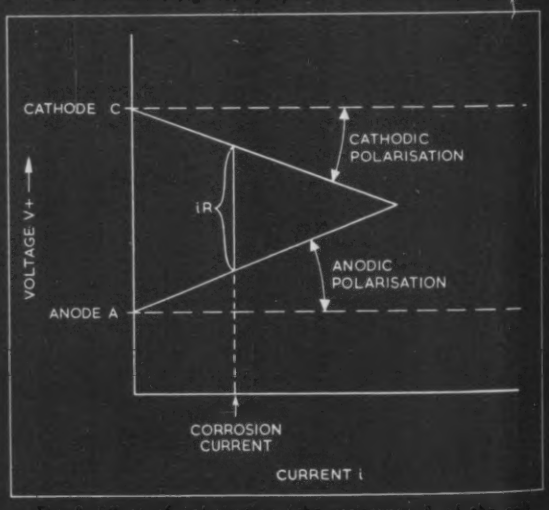


Fig. 8. Effect of polarization (the resistance R of the cell circuit determines the final corrosion current).

Considering the hydrogen evolution reaction, iron can precipitate hydrogen from solution if the electrode potential of the iron is more negative than the hydrogen potential. The precipitation of copper from solution by immersion of an iron rod is a well-known example of this type of reaction. Fig. 5 shows the variation of the hydrogen electrode potential with pH (logarithm of the reciprocal of the hydrogen ion concentration). The electrode potential of iron is also shown as independent of pH, but varying slightly with iron concentration in the solution. The iron will displace hydrogen from the solution if the pH is less than 9-10. For the evolution of hydrogen bubbles, however, additional energy must be supplied in the form of a hydrogen overvoltage. This overvoltage is dependent on the metal involved, the temperature, and other factors. A figure of 0·25 volts has been used for the conditions postulated, namely, a dilute solution of iron, temperature about 20 deg. C., and a current density approximating to the "bubble potential".

Before hydrogen gas is seen, therefore, the electrode potential betweeen the hydrogen and the iron must exceed the hydrogen overvoltage. This overvoltage appears in Fig. 5 as a line parallel to and above the hydrogen potential curve. The corrosion process with iron can now be seen to be hydrogen evolution and rapid corrosion at pH less than 4-5, a stable hydrogen film between pH 4·5 and 9·5 approximately, and at higher pH values no hydrogen corrosion.

Superimposed on the diagram in Fig. 5 is a curve showing the rate of corrosion of iron immersed in waters of various pH.[8] Corrosion is rapid with pH less than 4, steady over the range pH 4-10, and decreases steadily from pH 10 upwards. Fig. 6 shows the effect of oxygen concentration on the corrosion of iron. The rate of corrosion around the neutral point, pH 7, is seen to be a function of the oxygen concentration in the water. In this region of pH, in which most natural waters lie, the mechanism of corrosion is largely the depolarising effect of the oxygen removing the stable hydrogen film from the iron surface. At high pH values the corrosion is essentially by oxygen absorption and is controlled by the solubility of the iron hydroxide formed. Fig. 7 makes this point.

Similar arguments can be applied to other metals to determine the broad picture. Metals which have electrode potentials more positive than hydrogen over the whole range of pH can be expected to corrode by oxygen absorption rather than by hydrogen evolution; e.g., copper and its alloys. The metals with electrode potentials more negative than hydrogen at all pH values can be expected to corrode extensively by hydrogen evolution, e.g., magnesium and its alloys, although oxygen absorption is not excluded. High hydrogen overvoltages limit hydrogen evolution where corrosion would otherwise be severe; e.g., zinc and its alloys. Other factors such as protective oxide coatings may, however, supervene and make corrosion resistance much higher, as in the case of aluminium and its alloys.

Immersion Corrosion

Dissimilar metals in electrical contact develop a corrosion current between them when the circuit is closed by a conducting liquid. The negative metal becomes the anode and conducts current by dissolution in the liquid. The rate of corrosion of the anode is directly proportional to the current density on the anode, provided there are no local cells on its surface.

On initial immersion the voltage and the current flowing in the cell decrease rapidly and then more slowly, finally settling down at values generally much lower than the initial figures. This change is due to reactions occurring at either the anode or at the cathode or at both simultaneously. Considering cathode reactions first, the current flowing is the result of transport of positively and negatively charged ions through the solution. The positively charged ions migrate to the cathode, where they are discharged by electrons, resulting in deposition of the element, metal or hydrogen, on the cathode. The rate of discharge at the cathode surface is much faster than the rate of transport through the solution, so that the concentration of positive ions round the cathode is decreased. This local concentration effect alters the electrode potential of the cathode, making it more anodic. This concentration polarisation effect is reinforced by the potential shift at the cathode due to plating out of metal atoms or hydrogen, the latter effect being called hydrogen polarisation.

Corresponding concentration polarisation occurs at the anode, positive ions becoming concentrated round the anode surface and making the anode more cathodic. Negatively charged ions discharge on the anode, producing the salts of the anode metal. If these salts are insoluble and adherent, further shift of the anode potential will take place, since most of these compounds have high cathodic potentials. Increased electrical resistance in the circuit arising from film formation decreases the current flowing and reduces corrosion of the anode. Fig. 8 illustrates the effect of polarisation diagrammatically, the resistance R of the cell circuit determining the final corrosion current.

Inhibitors added to the corroding solutions operate by increasing the polarising effects, as shown in Fig. 9 and discussed later.

Corrosion can arise where a single metal is in contact simultaneously with two solutions having different concentrations of metal ions, oxygen or other constituents. These concentration cells produce localised corrosion. In the case of the oxygen concentration cell, for instance, the area in contact with the lower oxygen concentration becomes the anode and severe pitting can result. This effect is responsible for waterline corrosion, corrosion pits under droplets on metal surfaces, crevice corrosion and corrosion in circulating systems where zones of stagnant water become depleted in oxygen content. Cold pressing and forming operations produce non-uniform deformation in metals, the severely deformed areas frequently being anodic to the undeformed regions. Corrosion cells are set up where an oxide layer is cathodic to the underlying metal. Such is the case with mill scale on steels. Porous electrodeposited coatings which are cathodic to the base metal similarly will cause trouble.

Immersion Corrosion—Biological Factors—Corrosion can occur either as a result of the metabolic processes in organisms entering into the corrosion reactions, or by the growth of organisms providing conditions suitable for oxygen concentration cells to develop. As seen above, the corrosion rate of ferrous metals is governed mainly by the stability of the polarising hydrogen film. Under anaerobic conditions, such as in a clay soil, sulphate-reducing bacteria (*vibrio desulphuricans*) can utilise this hydrogen to reduce sulphates in the soil or water to form sulphides. As a result, cast-iron pipes $\frac{1}{2}$ in. thick can be reduced to graphite pipes, the iron having been dissolved out, in a comparatively few months.

The iron bacteria,[9] such as *gallionella ferruginea*, present in many natural waters, produce nodules within pipes which result in oxygen concentration cells when the water in the pipe is aerated. Serious pitting can thus occur within the space of a year or two.

At temperatures above 30 deg. C, and high relative humidities above 90 per cent, fungi such as moulds can grow readily. Growth on a clean metal is unlikely, but even a fingerprint enables growth to start. Growths of this nature produce conducting paths and permit electrolytic corrosion where otherwise it might not be expected. Oxygen concentration cells are formed and pitting can be severe, especially with the more corrosive metals like magnesium.

Prediction of Corrosion

While it is fairly easy to be wise after the event, the prediction of the degree and mechanism of corrosion where

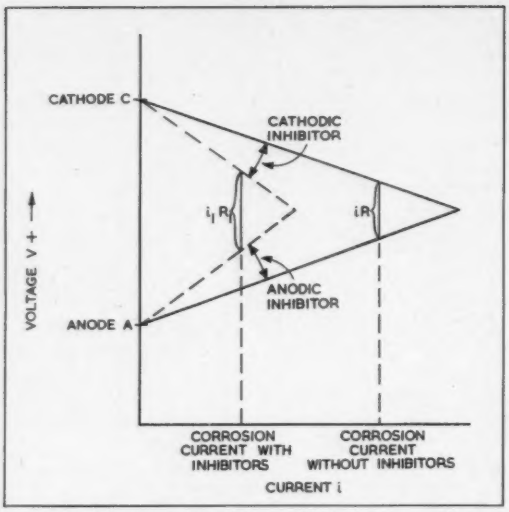


Fig. 9. Showing how inhibitors added to the corroding solutions operate by increasing the polarising effects.

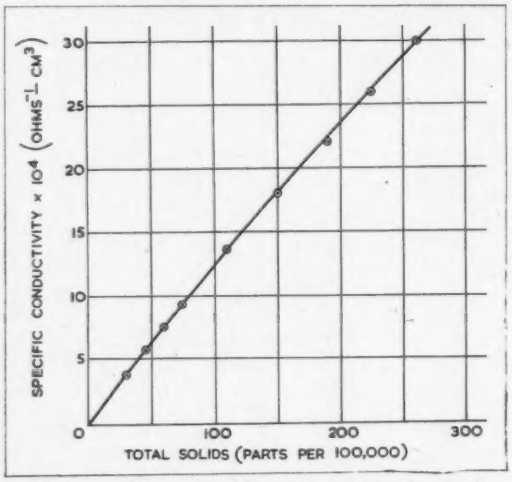


Fig. 10. Specific electrical conductivities of typical natural water compositions, as a function of total solids content for pH 7.

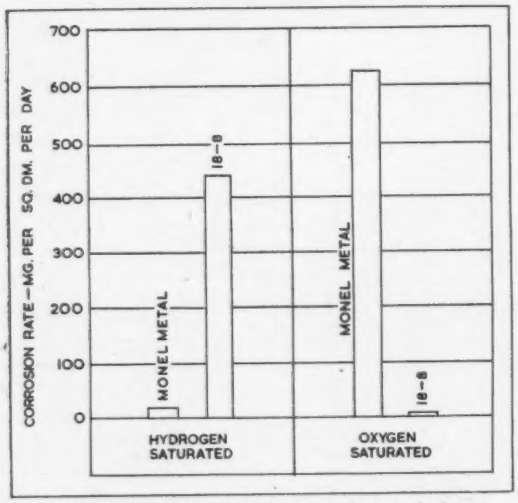


Fig. 11. Influence of oxygen on corrosion rate in 3 per cent sulphuric acid. (*Corrosion Resistance of Metals and Alloys*, Fig. 3.)

prior experience is lacking is a very difficult proposition. Nevertheless, much can be done given a background of experience and the opportunity to conduct preliminary tests.

Pumping, transport and storage of natural and treated water is a very common problem. Its brief examination can indicate the principles involved in tackling it. Since the cheapest materials of construction are generally cast iron and steel, their resistance to simple immersion corrosion by the water is first examined. To do so, a minimum amount of essential information must be available. Corrosion by hydrogen evolution and by oxygen absorption can be gauged, with experience, by measurements of pH, aggressive carbon dioxide, degree of aeration and the presence of corroding bacteria. pH is a simple measurement, but, like the estimation of carbon dioxide and oxygen, should be carried out on site if possible. An indication of agressive carbon dioxide can be inferred from the balance of carbonate, bicarbonate and carbon dioxide in the water, while in general the Langelier Index[10] can be measured by a simple test and is useful with some reservations.[11] Various methods are available for measuring dissolved oxygen, while fairly simple culture tests can be used to indicate the presence of dangerous bacteria.[12]

The possibility of electrolytic corrosion must be considered, and this can generally be inferred if the total solids (i.e., conductivity) in the water are high. Dr. A. L. Jones (R.M.C.S.) has calculated the approximate specific electrical conductivities of typical natural water compositions as a function of total solids content for pH 7. Fig. 10 shows a practically linear relationship. While it is unwise to be precise, a total solids content of more than 100 parts per 100,000 indicates probable electrolytic corrosion with steel and bronze in contact. Little corrosion with this couple will occur if the total solids are below 50 parts per 100,000.

The corrosion of containers during storage of petrols and oils is due mainly to the presence of water in excess of its solubility. A concentration cell effect is probably responsible, the oil and particularly petrol dissolving appreciable amounts of oxygen while the water globules at the bottom of the container become depleted in oxygen. When used as a lubricant, the oil may break down, due to the resulting temperature rise, causing release of organic and inorganic acids. Steels, copper alloys and bearing metals can show appreciable corrosion, particularly if water is present in the oil. Measurement of water content and acidity gives some indication of probable trouble in storage, but rig tests, although expensive, are probably necessary to assess corrosion in use.

Corrosion by solutions of chemicals involves so many factors that spool tests are essential. Most manufacturers of corrosion-resistant alloys publish tables giving the resistance of their products to a wide range of chemicals. Although usually in very general terms, this information can be used to design a series of corrosion tests. Corrosion textbooks such as those by Speller, Uhlig, and also McKay and Worthington provide a wide range of information on various chemicals.

Protection Against Corrosion

CHOICE OF MATERIALS—In the choice of materials, experience is of paramount importance. Nevertheless, the general principles already outlined can be of considerable assistance, but each problem must be treated in its own context. Cast iron and steel can be used where the hydrogen polarising film will be stable. Thus the pH should be less than 5, and the oxygen concentration less than about 0·2 ml./litre; aggressive carbon dioxide and sulphate-reducing bacteria should be absent. High concentrations of oxygen of the order of 25 ml./litre can passivate iron, although the situation is dangerous in view of the possibility of concentration cells.

Where serious corrosion of iron and steel is probable,

stainless steels and alloy cast irons or non-ferrous metals can be used. Where this is impracticable, special precautions such as cathodic protection should be employed. Stainless steels and alloy cast irons show good resistance where oxidising conditions exist, but copper and nickel alloys should be used where chemically reducing conditions persist. Fig. 11 illustrates this point.

If electrolytic corrosion is probable, all-iron-and-steel construction can be used where hydrogen evolution and oxygen absorption types of corrosion will not be serious. Otherwise it will be necessary to use stainless steel and alloy cast iron, or all-bronze construction. Frequently it is necessary to use dissimilar metals although electrolytic corrosion is expected. A rough indication of the compatibility of common alloys is given in Table 2 for a galvanic series derived from the much fuller data given by LaQue.[13] Usually adjustments can be made in the types of metal in immediate contact, and where this is not possible, the junction between incompatible metals can be designed to allow non-conducting washers or gaskets to electrically insulate the two metals. Failing this precaution, the application of a water resistant paint such as rubber or bitumen across the joint and several inches on either side will be a palliative.

COATINGS—Adherence is greatest with epitaxial coatings where the crystal structure of the metal and the coating is continuous. Such coatings can be obtained only as the result of a chemical reaction at the surface of the metal. Not all surface coatings formed in this way, are epitaxial, however, and many have little protective capacity. Naturally-formed films such as those on stainless steel and aluminium are self-healing, provided oxygen is available. The artificial thickening of the oxide on aluminium by anodising gives greatly increased protection. Such coatings, however, confer cathodic properties on the metal, but their high electrical resistance cuts down the corrosion current when in contact with anodic metals.

Selective oxidation, by controlling the oxidation process to preferentially oxidise one of the constituents in an alloy, can give very good protection; e.g., aluminium in copper or silver can prevent tarnish.

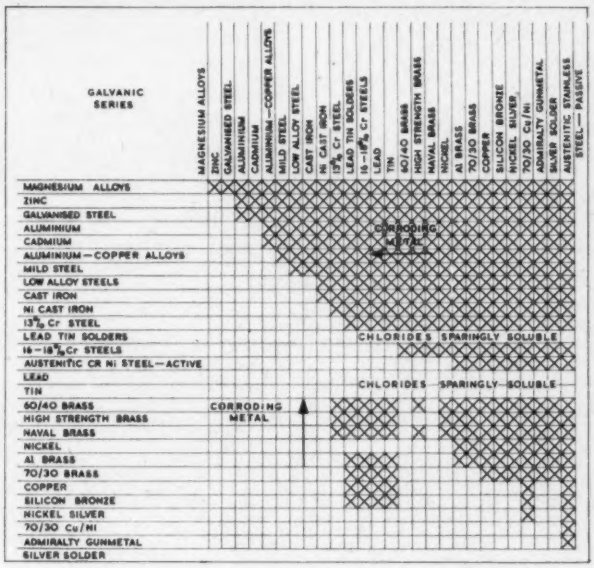
The marked improvement in recent years in the protection given by paint films has been brought about by three factors: proper preparation by acid pickling, anodic pickling or sand blasting removes oxide and roughens the surface, giving improved adherence; coatings of phosphate, particularly manganese and iron phosphates on steel, produce insoluble films which aid adherence and resist moisture penetration through the paint film; thirdly, considerable improvement in the mechanical properties of paint films has increased resistance to mechanical damage.

Electrodeposited coatings can give good protection but, when thin, they are porous and corrosion spots soon appear, particularly if the coating is cathodic to the base metal. Anodic coatings give better protection, but do not give the attractive surface finishes. Hot dipped coatings such as galvanising, being thicker, give superior protection but inferior surface finish to electroplated films.

Cladding of various kinds is available, such as pure aluminium on strong aluminium alloys. Sheet steels clad with nickel, Monel metal, stainless steel and other materials are also produced. Provided the designer ensures protection of the exposed edges, these materials can be used for a wide range of applications. A recent development is the p.v.c. cladding of steel sheet. This plastics-coated sheet can be cold formed in the same fashion as other clad materials, and can also be embossed with patterns.

CATHODIC PROTECTION—This consists essentially in making the corroding metal the cathode in an electrolytic cell, the anode being expendable and easily replaced. The anode can be scrap steel, cast iron or graphite, and the current can be provided by batteries, a generator, or rectified a.c. from a power line. Alternatively, enough current can often be provided by zinc, magnesium or aluminium anodes connected to the corroding structure. The correct design of a cathodic protection system requires preliminary tests, which must be carefully interpreted. Alkali corrosion of the cathode, shielding effects, and induced corrosion at insulated joints are only some of the difficulties which can arise.

Table 2. Compatibility of dissimilar metals in contact with sea water.



INHIBITORS—Inhibitors function by modifying the cathode or anode reactions. Anodic inhibitors are generally soluble salts which form insoluble compounds with the anode metal. Common anodic inhibitors are soluble chromates, phosphates, nitrites, hydroxides and carbonates. While anodic inhibitors can be very effective, sufficient inhibitor must be present, otherwise the anode surface is not completely covered, the current is concentrated at the bare areas, and severe pitting results. Corrosion with inhibitors present can occur where crevices and stagnant zones prevent a continuous supply of fresh inhibitor.

Cathodic inhibitors, while safer, are generally not so effective as anodic inhibitors. Some cathodic inhibitors raise the hydrogen overvoltage on the cathode, thus slowing down hydrogen evolution. Other cathodic inhibitors produce insoluble salts on the cathode by reacting with the alkali produced from oxygen absorption.

Adsorption inhibitors are mainly organic complexes and colloids. They probably function by mechanical interference with the surface reactions on the electrodes. Vapour phase inhibitors, frequently used as impregnations on wrapping papers for packaging, are possibly adsorption inhibitors.

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DESIGN AND APPLICATION OF EXTERNALLY-PRESSURISED AIR BEARINGS

The National Engineering Laboratory has recently been carrying out experimental work on the design and application of externally-pressurised air-lubricated bearings—this article describes some of the progress which has been made

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THE first section of the following article deals with the general principles of air bearings, and mentions the properties which make them particularly useful in certain applications, together with their limitations. The next section gives a brief description of some experimental work done to provide design data for a particular form of flat pad bearing. From the results obtained in this investigation, empirical formulæ have been developed and these can be used to relate the various design parameters of such a bearing. In the final section of this article, some typical applications of air bearings are described in order to illustrate the ways in which the useful properties of this type of bearing can be exploited.

General Principles and Properties

Air-lubricated bearings can conveniently be divided into two types, commonly known as self-acting and externally-pressurised bearings.

The self-acting air bearing is one in which no compressed air supply is required, but which builds up an air pressure in the clearance between the moving and stationary parts of the bearing due to the relative motion between the two parts. It can assume the form of a journal bearing, where the shaft takes up an eccentric position when in rotation and hence forms a "wedge" of pressurised air which is drawn in from the atmosphere and which supports the weight of the shaft and any external load. In the case of a self-acting thrust bearing, it is usual to make the thrust faces in the form of tilted pads to enable the pressure to build up, and in this way the bearing resembles the conventional form of Michel oil thrust bearing.

The advantages of self-acting air bearings are simplicity of construction and the absence of an external air supply. On the other hand, since their operation depends on a speed effect, it is necessary to ensure that the shaft and bearings are not damaged during the starting-up period, and this can be achieved to some extent by suitable matching of the materials of the shaft and bearing. This type of bearing is, of course, not suitable for stationary or slow-moving bearings, such as gimbals, etc.

Information on the theory and design of self-acting air bearings is given by, among others, Ford, Harris and Pantall[1] and Cole and Kerr.[2] Since the majority of applications described in the latter part of this article are concerned with slow-moving or stationary bearings, no further mention is made of self-acting air bearings.

The second type of air bearing is known as the externally-pressurised bearing. In this case, air under pressure is admitted into the bearing clearance through a number of small orifices, and is then allowed to escape through the bearing clearance to atmosphere. Fig. 1 shows a cross-section through a typical pad bearing. The two orifices shown are connected by internal manifolds to a supply of compressed air. Under these circumstances the pressure in the clearance at the orifice is a function of the clearance dimension. As

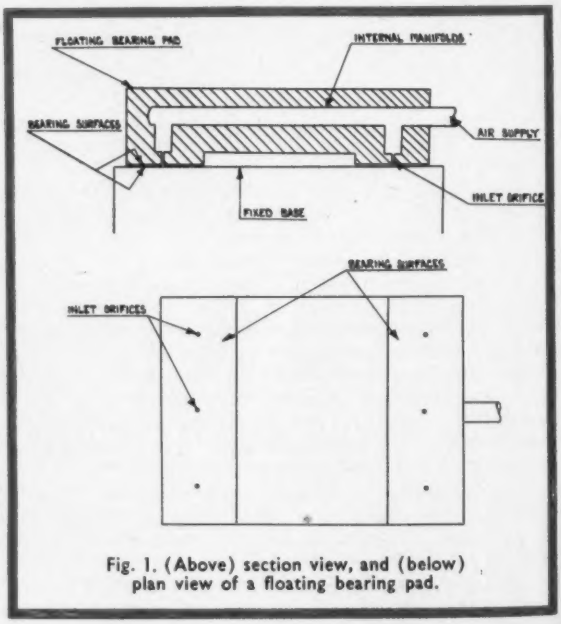

Fig. 1. (Above) section view, and (below) plan view of a floating bearing pad.

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this is decreased, the pressure increases, until with zero clearance the pressure at the orifice is equal to the supply pressure. It can therefore be seen that as load is applied to the floating bearing member, the clearance will adjust itself, until the air pressure is just sufficient to balance the load; the ultimate load on the bearing is reached when the pressure at the orifice exit rises to the supply pressure value; i.e. when the bearing clearance is zero. This applies both to a thrust or pad bearing, where there is only a single air film, and also to a journal bearing, where the load is balanced by the difference of the air pressures on the two sides of the shaft.

The advantages of this type of bearing include negligible friction both at rest and while running at speed, and the ability to increase the load-bearing capacity of a given bearing by increasing the supply pressure. There is another major advantage which obtains mainly when the bearing is used as part of a precision measuring instrument. The truth of running of an air journal bearing at slow speed and constant radial load is much greater than would be expected from the dimensional accuracies of the component parts. As will be seen, this means that it is possible to produce, by normal turning and grinding methods, a bearing running to an accuracy of 5 micro-inches.

The main disadvantage of the externally-pressurised air bearing lies in the fact that a constant supply of reasonably clean compressed air is required. In a fractional horsepower motor running on air bearings, which is described in a later section of this article, the horsepower required to supply the compressed air exceeds that of the motor itself by a factor of about 3 to 1. In deciding on the choice of air bearings for any particular application, it is therefore always necessary to ensure that the favourable factors in the form of lack of friction, lack of wear, etc., are of sufficient importance to justify the expenditure on air supply.

Information both on the theory and design of externally-pressurised air bearings is given by several authors, including Mueller,[3] Shires,[4] etc. Work is also being carried out at the National Engineering Laboratory to determine the design characteristics of a particular form of air bearing and this, together with the results obtained, is briefly described in the following section.

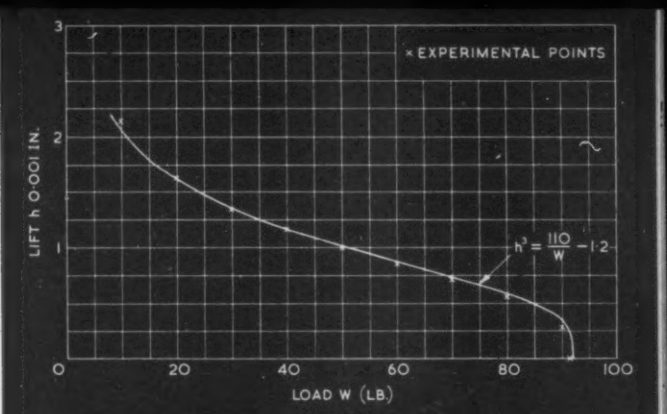

Fig. 2. Comparison of results obtained from design formula and from practical tests.

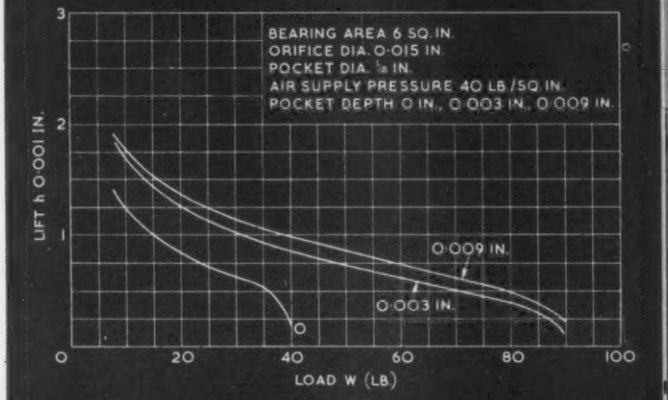

Fig. 3. Typical load-lift curves for a flat pad air bearing.

Design Data for Flat Air Bearings Operating under Steady-load Conditions[5]

Although pressurised air bearings have been used previously in many applications, these have been designed mainly by trial and error methods, and have not necessarily been operating under the best conditions of stiffness, load capacity, air flow, etc. It was decided, therefore, as a first step, to carry out some experimental work to determine the optimum design of one form of bearing, i.e. a flat-pad bearing, as might be used in slideways, etc.

The form of bearing chosen (similar to that shown in Fig. 1) had six orifices arranged in two sets of three in such a way that each orifice was at the centre of a square bearing area. Two bearing sizes were used, the first consisting of two pads $4\frac{1}{2} \times 1\frac{1}{2}$ in. (i.e. a total of $13\frac{1}{2}$ sq. in. area), and the second of two pads 3×1 in. (i.e. 6 sq. in. area). The air admission orifices were drilled in detachable plugs, so that it was possible to vary the orifice diameters. This arrangement also made it possible to set the orifice flush with the bearing surface or back from it by any desired amount.

Air was admitted to all six orifices by internal manifolds, so that only one external air connection to the bearing was required. The bearing surfaces were ground and lapped, and the bearing floated on a baseplate finished in a similar way. External loads were applied to the bearing by means of a wire attached to it and passing through the baseplate with a weight carrier at its lower end.

The variations in air film thickness, i.e. in lift of the bearing, were measured to an accuracy of better than 0·0001 in. by means of four air gauges situated at the corners of the bearing. The airflow to the bearing was measured by means of a rotameter in the air supply line.

The following design parameters were used in the course of the tests:

1. Air supply pressure 40 p.s.i. gauge (some subsidiary tests were also done at 20, 60 and 80 p.s.i.).
2. Bearing area $13\frac{1}{2}$ and 6 sq. in.
3. Orifice diameters 0·010, 0·015, 0·020, 0·025 and 0·030 in.
4. Orifice pocket diameter $\frac{1}{2}$ in.
5. Orifice pocket depths 0, 0·003, 0·005 and 0·009 in.

Fig. 3 indicates the general relationships between lift and load which were obtained in the course of these tests. From a considerable number of these the following qualitative conclusions regarding the properties of this type of air bearing were drawn:

Load-bearing Capacity—This is not influenced by the orifice diameter in this type of bearing. It does, however, depend on the orifice pocket depth in so far as it increases with increase of pocket depth up to a certain value, beyond which increase of pocket depth exerts no influence. The load-bearing capacity is directly proportional to both bearing area and supply pressure and can be expressed by the formula:

$$W_{max} = K.PA$$

where W_{max} = ultimate load-bearing capacity;
P = air supply pressure (gauge);
A = bearing area;
K = constant factor, depending mainly on the orifice pocket dimensions.

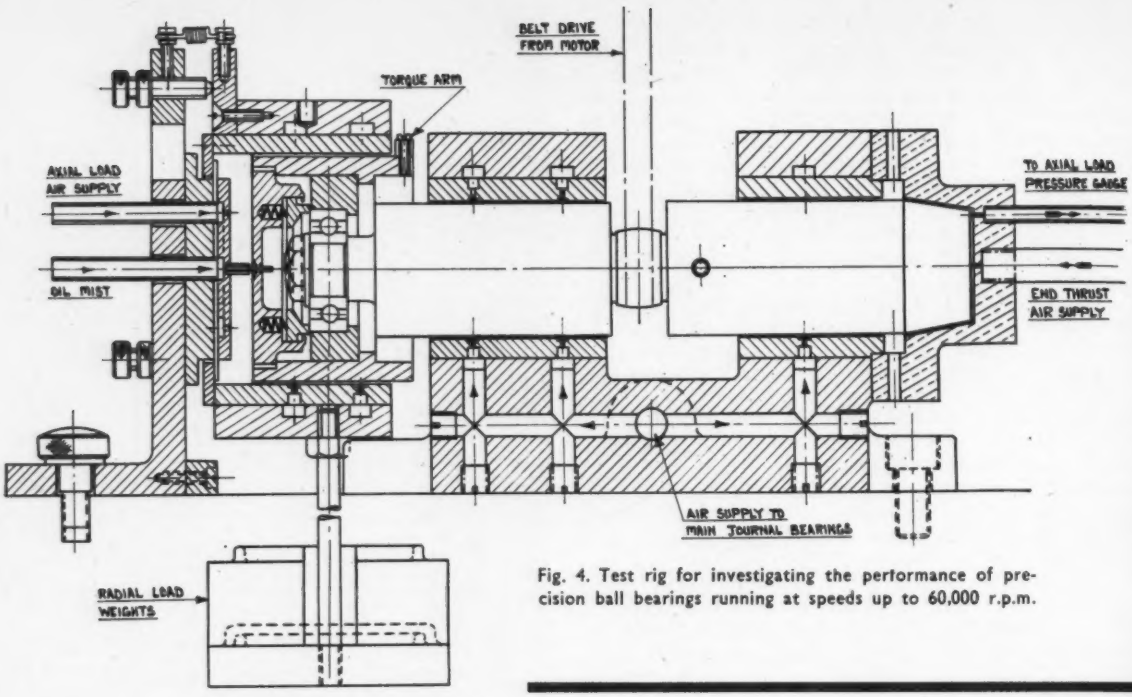

Fig. 4. Test rig for investigating the performance of precision ball bearings running at speeds up to 60,000 r.p.m.

For bearings of the type used in these tests, the factor K was about 0·22 for no orifice pocket, and 0·37 for a pocket of 0·009 in. depth. This latter value seems to be about the maximum for the pocket area used. Larger pockets were tried in these tests, but no conclusive results were obtained due to the occasional occurrence of self-induced vibration. This matter is still under investigation.

BEARING STIFFNESS—This is defined as the change in load required to produce unit change in lift. As will be seen from the curves in Fig. 3, this quantity varies with the load on the bearing. It decreases with increasing orifice diameter but is not greatly influenced by pocket depth. For any particular bearing, the stiffest part of the load-deflection curve is between 0·5 and about 0·9 ultimate load, and it is desirable, where possible, to design for this condition. The effect of bearing area on stiffness is rather more complex, and can be evaluated from the formulæ given below.

In order to be able to appreciate the relationships between the various design parameters used, the experimental results have been evaluated mathematically and the following formulæ obtained. These all apply to a supply pressure of 40 p.s.i. gauge.

For an orifice pocket of 0·009 in. depth:

$$h^3 = \frac{a}{10^5}(5{\cdot}9A/W - 0{\cdot}38)$$

where h = lift (or escapement gap) (in.);
a = area of each orifice (sq. in.);
A = bearing area (sq. in.);
W = load (lb.).

For an orifice pocket of 0·003 in. depth, the corresponding expression is:

$$h^3 = \frac{a}{10^5}(3{\cdot}5A/W - 0{\cdot}26).$$

For no orifice pocket:

$$h^3 = \frac{a}{10^5}(1{\cdot}4A/W - 0{\cdot}16).$$

Corresponding values of bearing stiffness (S lb./in.) for 0·009, 0·003 in. and no orifice pocket depths are:

$$S = \frac{24W^2}{Aa^{1/3}}(5{\cdot}9A/W - 0{\cdot}38)^{2/3}$$

$$S = \frac{40W^2}{Aa^{1/3}}(3{\cdot}5A/W - 0{\cdot}26)^{2/3}$$

$$S = \frac{100W^2}{Aa^{1/3}}(1{\cdot}4A/W - 0{\cdot}16)^{2/3}.$$

From these expressions it is possible to evaluate all the relevant design factors for this type of bearing. Although strictly speaking these results only apply to the form of bearing tested, they have been applied with negligible error to longer bearings (up to 30 in.) of 1½-in. width, provided that the orifices are so arranged that their separation is equal to the bearing width. In other words, each orifice is situated in the centre of a square bearing area.

As an example of the use of these formulæ, Fig. 2 shows the relationship between the lift, h, and the load, W, derived from the formulæ for a bearing having an area of 6 sq. in., six orifices of 0·020 in. diameter and pockets of ⅛ in. diameter and 0·009 in. deep, with an air supply pressure of 40 p.s.i. For a bearing designed in this way, the relevant formula connecting h and W becomes:

$$h^3 = \frac{110}{W} - 1{\cdot}20$$

where h in the formula is the lift in 0·001-in. units;
W is the load in lb.

The individual points plotted on top of the curve in Fig. 2 are derived from actual tests and demonstrate the agreement between the empirical formulæ and practice.

Application of Externally-pressurised Air Bearings

In view of their various favourable properties (lack of friction, lack of wear, etc.), air bearings have been used in a variety of ways at the National Engineering Laboratory. These include both high-speed and low-speed application and both journal and thrust or slider bearings. Some of these applications are described in this section.

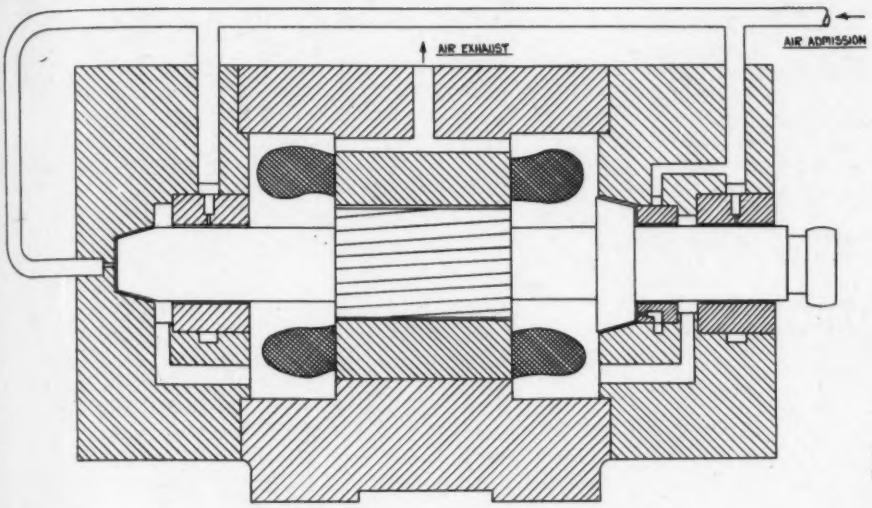

Fig. 5. Section view of the variable-speed ¼-h.p. motor used to drive the test rig shown in Fig. 4.

HIGH-SPEED TESTING MACHINES FOR PRECISION BALL BEARINGS—Two machines have been developed at the Laboratory to investigate the performance of small bore (5-15 mm.) precision ball bearings running at speeds up to 60,000 r.p.m. The first of these[6] provides a continuous record of frictional torque in the bearing at various radial and axial loads. Because of the high speeds involved and the need to reduce vibration to a minimum, it was decided to use air lubrication for all bearings in the test rig. In order to be able to use the rig at low as well as at high speeds, externally pressurised bearings were chosen.

As shown in Fig. 4, the ball bearing is mounted at the end of a shaft supported on two air lubricated journal bearings. According to the specification for the test rig, the maximum loading on the ball bearing had to be 20 lb. in both axial and radial directions. To allow for this degree of asymmetric loading on the air journal bearings, the bearing nearest to the applied load was made larger than the other one, the sizes being 1½ in. diameter by 2 in. long and 1¼ in. diameter by 1½ in. long respectively. The air is supplied to the smaller bearing by one row of three orifices, each 0·025 in. in diameter. The larger bearing has two rows of orifices, ½ in. from each end with three orifices of 0·025 in. in each row and an additional 0·010-in. orifice at the bottom of the bearing. This arrangement tends to compensate for the asymmetric loading, which is always in a downward direction on the larger bearing. To improve the load bearing capacity,[5] each orifice has a pocket of 0·005 in. maximum depth and ¼ in. square section machined at its inner end, using a milling cutter of ¼ in. width. The radial clearance between shaft and bearing is 0·001 in. With an air supply pressure of 60 p.s.i., the maximum radial load which could be applied to the ball bearing was 25 lb.

The outer race of the ball bearing is held in a housing which forms the inner part of an air bearing providing a frictionless pivot. This again has two rows of three orifices and is of similar design to the journal bearing described above. The radial load on the ball bearing is applied by dead weights and transmitted through the airfilm of this bearing. The torque arm used for the measurement of friction torque is carried on the ball bearing housing.

Axial load on the ball bearing is applied by air pressure as shown in Fig. 4, and the reaction to this load is provided by a conical air thrust bearing at the other end of the shaft. In this case air is admitted through one central orifice to the space between the end of the shaft and the bearing, and escapes to atmosphere along the conical surface. This form of bearing enables the load-bearing capacity to be increased for a given size of shaft, and increases the running clearance at the thrust bearing.

The test bearing on its shaft is driven by a variable-speed ¼-h.p. motor by means of a silk belt. The squirrel cage rotor is mounted on two air journal bearings 1 in. in diameter by 1 in. long with three orifices of 0·020 in diameter arranged symmetrically in each bearing. The radial bearing clearance is 0·001 in. Conical air thrust bearings are also provided. A cross-section of the motor is shown in Fig. 5. With an air supply pressure of 60 p.s.i. the motor is capable of taking a load of 20 lb. at the pulley. Most of the exhaust air from the bearing is used to cool the stator windings of the motor, thus making separate water cooling unnecessary.

The total air supply required for this test rig is 12 cu. ft. of free air per minute. The original machine has now been in use for six years with a total running time of 15,000 hours, and no sign of wear or deterioration in any of the air bearings has been noted. A second similar machine[7] has been developed to measure the vibration in ball bearings at speeds up to 60,000 r.p.m.

ROUNDNESS MEASURING MACHINE—In the early stages of the work on air bearings carried out at the Laboratory, a vertical journal bearing with a flat thrust bearing was constructed to provide a rotating table for measuring purposes.[8] This is shown in cross-section in Fig. 6. It consists of two air journal bearings 1¼ in. in diameter by 1¼ in. long, together with an annular air thrust bearing of 4½ in. o.d. by 1¾ in. i.d. Each journal bush has six symmetrically spaced orifices of 0·015 in. diameter with pockets of the same design as in the previous example. The radial bearing clearance is 0·0005 in. The thrust bearing has six equally spaced 0·015 in. diameter orifices connected by a groove ¼ in. wide by 0·005 in. deep.

Measurements carried out on this bearing indicated that its axis of rotation remained steady in space to an accuracy of better than 5 micro-inches under constant load and slow speed conditions. Moreover, this rotational accuracy was achieved with conventional production methods and is unchanging with time, since no wear takes place in this type of bearing. The free air consumption is approximately 2½ cu. ft./min.

Based on this design, a roundness measuring machine[9] has now been developed and is being produced commercially. As its reference axis it employs a bearing similar to the one described above. An air gauging measuring head is carried at the lower end of the shaft, and its stylus is arranged to contact the work. The signal from this air gauge is amplified and fed to a circular chart pneumatic recorder, giving an overall magnification of 5,000:1. In this way, circular chart records of the roundness of a test piece can be obtained with ease. The complete bearing and gauging unit is mounted on a conventional toolmaker's microscope, to enable the test piece to be set up concentric to the reference axis of the bearing.

AUTOMATIC LEAD-SCREW PITCH MEASURING MACHINE—An automatic machine has been made at the Laboratory for the measurement of pitch errors in standard lead screws. The method of measurement employed is based on the use of diffraction gratings with photocell sensing devices. One of the requirements in this machine is a carriage or saddle moving along a girder with minimum deviations from linear motion, and preferably without stick-slip friction. In the prototype machine a girder 6 ft. long and 6 in. wide and a carriage weighing about 80 lb. were employed. For the initial tests this carriage was supported on three precision ball bearings, and three more were used to provide sideways location. At a later stage these ball bearings were replaced by four flat air bearing pads to take the weight of the carriage, and four more to provide sideways location (shown in Fig. 7).

Employing an autocollimator and a precision level, comparative tests were carried out on the carriage fitted with the two types of bearing to determine the amount of rolling, pitching and yawing, as the carriage moved a distance of 9 in. along the girder. These results are given in Fig. 8, and show that a considerable improvement in the accuracy of movement has been achieved by the use of air bearings. This is due partly to the elimination of the effects of errors in the ball bearings, and partly to the greater effective bearing area of the air bearings, which tends to result in the maintenance of a constant mean air gap regardless of local irregularities of the girder surface.

As a result of these preliminary tests, a larger carriage

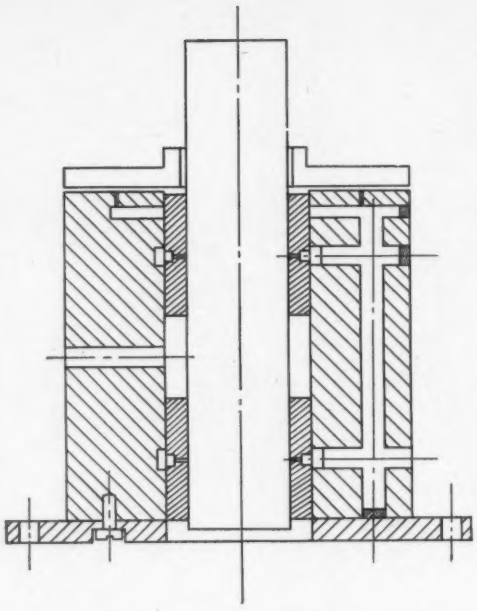

Fig. 6. Section view of a vertical journal bearing with a flat thrust bearing constructed to provide a rotating table for measuring purposes.

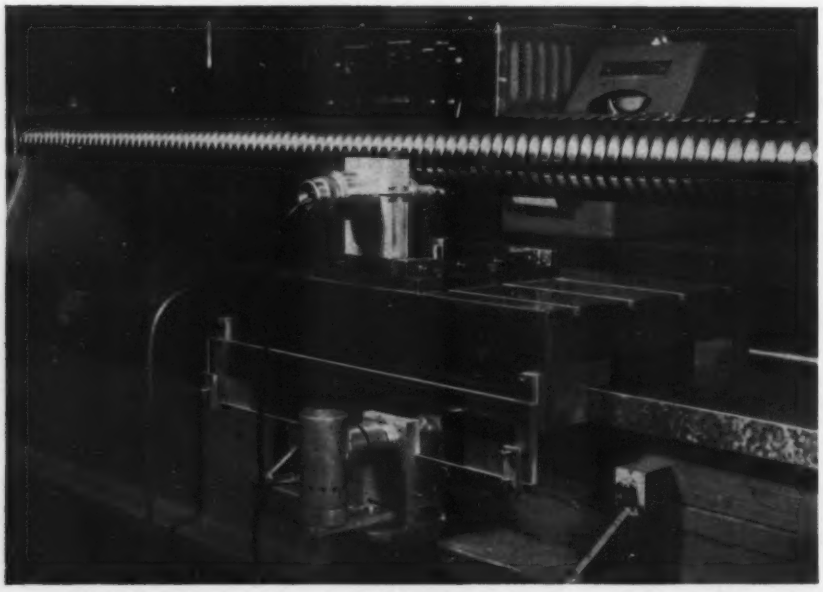

Fig. 7. Automatic machine developed for the measurement of pitch errors in standard lead screws.

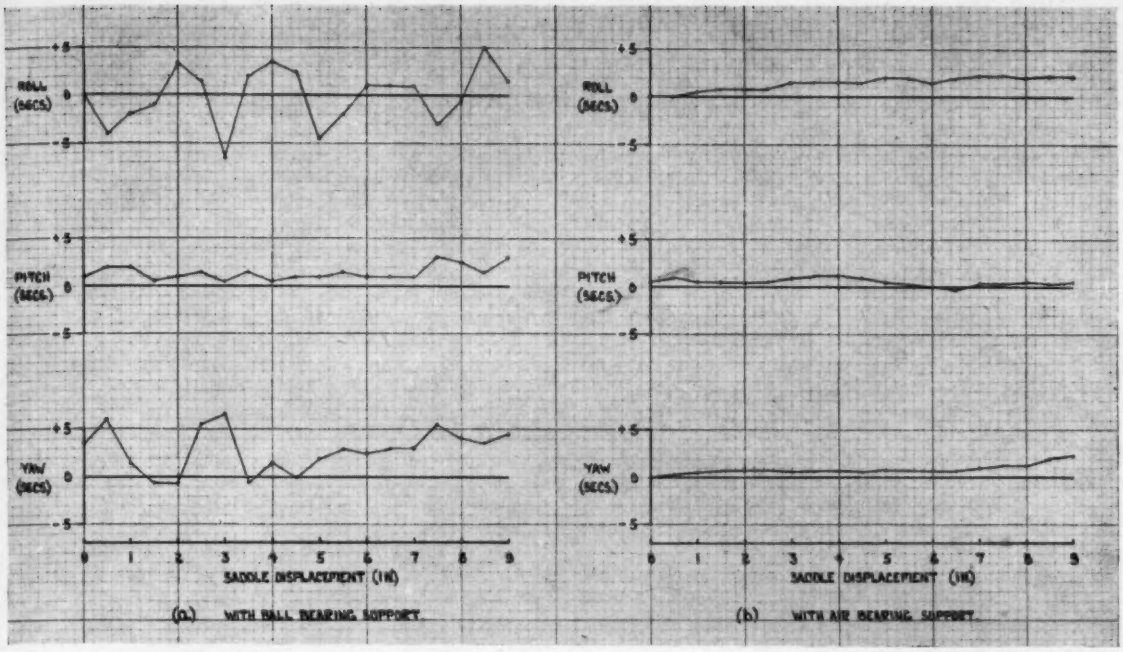

Fig. 8. Results of comparative saddle performance tests carried out on a carriage fitted with two types of bearing.

has now been constructed and is being used in conjunction with an 18 ft. long girder. In this the four bearing pads are each 4½ in. × 1½ in. with three orifices of 0·020 in. diameter. This design is based on the results of the tests mentioned in a previous section of this article, and has been found to be quite satisfactory.

Preliminary work is also proceeding to investigate the possibility of using this form of air bearing for machine tool slideways. If successful, this will have the highly desirable effect of eliminating stick-slip friction, which is of special importance in computer-controlled machine tools.

FRACTIONAL HORSEPOWER DYNAMOMETER—A precision fractional horsepower dynamometer[10] has been developed to measure the losses in small transmission units such as gearboxes, variable speed mechanisms, etc., to an accuracy of ±0·1 per cent relative to the full load torque of 27 lb. in.

The basic principle of operation is the measurement of torque reaction on the stator of the driving motor or absorbing generator, since this torque reaction is always equal to the shaft torque. To achieve this, both units are trunnion mounted on air bearings to eliminate friction, and the torque is measured by an electromagnetic torque balance.

The air journal bearings are 5 in. in diameter by 1 in. long, and the thrust bearings are annular rings of 1 in. width. The radial bearing clearance is 0·001 in., and the air supply orifices are 0·020 in. in diameter with pockets at their inner ends. Since the load on the bearings is always in a downward direction, the five orifices used in each journal have been spaced asymmetrically towards the lower part of each bearing. The thrust bearings have three orifices of 0·020 in. diameter connected by an annular groove ¼ in. wide × 0·005 in. deep. The total air flow to the bearings on both driving and absorbing units at a supply pressure of 60 p.s.i. is approximately 9 cu. ft./min.

Conclusion

This article describes the general principles and properties of pressurised air bearings, and gives some information on the design of such bearings. It also mentions some typical examples of their application. From these it can be seen that pressurised air bearings should only be employed in cases where their particular properties can be put to good use; in other words, if it is necessary to obtain a bearing with negligible starting or running friction, freedom from vibration, long life or high running accuracy, then the expenditure on the necessary air supply is justifiable and air bearings can be used with advantage.

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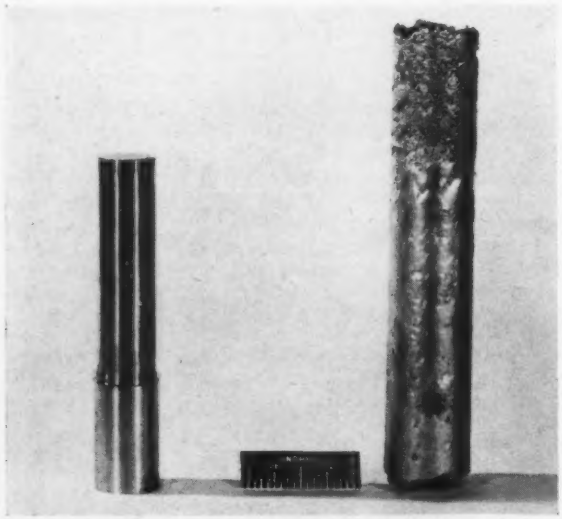
The work on externally pressurised air bearings forms part of the research programme of the Mechanisms, Metrology and Noise Control Division of the National Engineering Laboratory. This article is published by permission of the Director of the N.E.L.

DUCTILE TUNGSTEN

TUNGSTEN is one of the heaviest of metals, and is normally made into sheet, rod and wire by powder metallurgy techniques. While its use as a metal in its own right has in the past been largely confined to component parts of lamps and valves (i.e., filaments and anodes), it is finding increasing use in mechanical and structural components.

Tungsten is one of the few metals that possess structural strength at elevated temperatures. Its extremely high melting point (3,410 deg. C.), hardness and corrosion resistance make it a desirable material for high-temperature equipment. However, until recently, the high-temperature properties of tungsten could not be effectively utilised, its brittleness and hardness preventing it from being machined by conventional methods, and its weight restricting its uses in aeronautical equipment. For these reasons, efforts were made to develop a practical method for depositing tungsten coatings.

High purity tungsten can now be plated on metal surfaces by vapour deposition processes developed independently by the National Bureau of Standards and the Bureau of Mines. These methods are similar in that they involve reducing gaseous tungsten hexafluoride with hydrogen by passing it over the heated object to be plated. At temperatures above 300 deg. C. tungsten is deposited on the hot surface, and the only other reaction product, hydrogen fluoride, passes out with the excess of hydrogen.



Typical vacuum arc-cast ingots (d.c. reversed polarity) (*left*) after machining, and (*right*) as cast.

Vacuum arc-cast tungsten (*left*) as cast, and (*right*) low-velocity extruded (stainless-steel jacket).

By this method, it is possible to coat both simple and complex surfaces such as rocket and missile nozzles and jet engine parts. The technique also lends itself to the fabrication of tungsten articles, and may be a way of producing complicated shapes. Simple tungsten shapes for use in vacuum tubes have already been fabricated.

Spectrochemical examination has shown that the tungsten obtained by vapour deposition is purer than ordinary commercial tungsten, silicon being the only impurity present in a concentration of 0·1 per cent or more. The deposited metal also has the theoretical density of pure tungsten, 19·3 gm./cm.^{3}, which is higher than that of tungsten compacts produced by powder metallurgy or by flame spraying, and which suggests that plating eliminates the very tiny holes between tungsten particles which result from the other two processes. The hardness of the deposits obtained at 650 deg. C. is about 475 VHN, or about the hardness of ordinary commercial tungsten. The crystals deposited at 900 deg. C. are not as hard (410 VHN), indicating a slightly higher degree of purity.

Investigation into the adhesive bond between the tungsten coating and various basic materials showed that adhesion to molydenum and nickel was good, to copper somewhat weaker, and to iron rather poor. The tungsten-graphite bond was about as strong as the graphite itself. Tungsten deposited on ceramics also showed good bonding.

The work carried out by the Bureau of Mines has been primarily directed towards making tungsten by a bomb reduction. Although the metal is completely fused in processing, it is somewhat porous, varying in density from 50-80 per cent of the theoretical; at present only a cursory examination of the properties of tungsten prepared by this method has been made. Investigations under the sponsorship of the National Aeronautics and Space Administration have suggested that tungsten produced by arc melting and extrusion may be more ductile than that produced by the conventional powder metallurgy technique.

Initial attempts to melt tungsten using direct current with negative electrodes were unsuccessful, but with positive electrodes the tungsten was melted at a very rapid rate. This high melting rate probably limits the purification that can be achieved, since little time is available for volatilisation of impurities from the electrode and molten pool.

The undesirable characteristic of arc-cast tungsten is the very coarse columnar grain structure of the ingots, the embrittling impurities such as oxides tending to concentrate in the grain boundaries. Extrusion appears to be a promising method for grain refinement of this material. Although conventional low-velocity extrusion attempts with reduction ratios up to 5·5:1 were successful at 1,260 deg. C., extrusion at higher temperatures (i.e., above 1,650 deg. C.) appears desirable.

The results of tensile tests at 540 deg. C. indicated only slight differences in the ultimate tensile strengths of tungsten (approximately 70,000 p.s.i.) produced by the following methods: (a) Vacuum arc-cast and low-velocity extruded; (b) sintered and low-velocity extruded; and (c) sintered and swaged (commercial rod stock).

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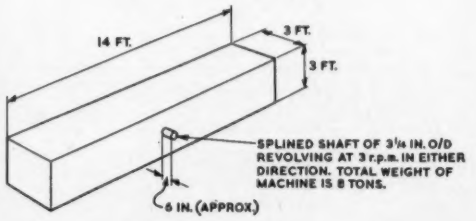
Conference on Research and Progress on Tungsten, O.T.S., PB 161013.

PROBLEMS IN DESIGN

Problem No. 11 (September): Some apparently clumsy devices have, despite many attempts to improve them, retained the favour of either manufacturer or user. Such a device is the common shackle for joining chains. This month's problem is to suggest a new design that will: (a) perform all the functions of the traditional design; (b) have no loose parts; (c) have no springs or delicate pivot pins to go wrong; (d) be capable of withstanding the arduous conditions of wear and corrosion encountered on ships, etc.; and (e) be as cheap to manufacture as the present design.

PROBLEM IN DESIGN No. 14
Here is this month's problem



This is a problem for the development and test engineer. For the testing of a number of special-purpose hydraulically-driven machines of large size, it was necessary to devise a piece of equipment that could absorb a very high torque. Available dynamometers were useless.

A 3¼-in.-dia. splined shaft projects about 6 in. from the side of the machine, which is of approximately the shape indicated diagrammatically above. The shaft revolves at 3 r.p.m. in either direction. The load testing device must be capable of absorbing an infinitely variable load, from zero up to a maximum of 6 h.p., for a period of 1 hr.

The energy-absorbing device is necessary to study the behaviour of the machine, in workshop conditions, under quarter, third, half and full load, and if possible should not incorporate gears to step up the shaft speed. If gears are used to bring the torque to manageable proportions, the nature of the gearbox must be given. Briefly, the problem is how to absorb so much energy from a shaft revolving so slowly, and at the same time measure the torque.

Entries should provide a good indication of how the problem should be tackled, with appropriate sketches.

Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12×12 in., please!), to the Editor, "Problems in Design No. 14 (December)". Closing date January 12.

Visit to the Patent Office

To suggest an improved form of a device that is already very simple can be as difficult, if not more so, than designing a complex mechanism. In the adjudication of the surprisingly large number of entries we received for the above problem, it was decided first to examine these on their merits and then visit the Patent Office to see what had been done to improve the common chain shackle in the past hundred years or so. The records were examined as far back as 1855 as carefully as could be done in the time available. Although there may be several Patents we missed in our search, we are fairly confident that several of those entries submitted are original. Others, no less ingenious, have been anticipated in the last century or in more recent times.

In recent years most of the Patents filed under the category which deals with hooks, shackles, etc., have been special-purpose devices which, although they can be used for joining chains, are really intended for special duty. Thus a recent Patent granted to K. A. Kjolner (Pat. No. 825,575) is a special-purpose device operated by a cable, and H. F. Heywood's Patent (No. 677,224) uses a sheet metal slider to "mouse" the chain ring, and was, we believe, used on parachute harness. In order to find basically simple inventions of the kind anticipated when the problem was set, we found it necessary to go back to the beginning of this century. We were surprised that no entries were received of the "sister hooks" variety, that very simple device used in sailing. In arriving at our decision as to which entries to publish, we are aware that we have actually allowed several which do not quite satisfy the conditions. Some would undoubtedly be more expensive to manufacture, while others might be difficult to make in a form which would be as strong as the chain links.

The common chain shackle can be a device for joining two lengths of chain together, or it may be attached to a drilled lug for lifting. If the hole is drilled, a hook type of shackle might be difficult to fit. Most of the entries were of the hook type, presumably because the problem mentioned only the joining of chains. In making our comments on the published entries, we refer to Patent Nos., and we would remind our readers that, prior to 1915, both Patent Application No. and final Patent No. are the same, and the year as well as the Patent No. must be specified. After 1915, the final Patent Nos. carry six figures, and it is not necessary to specify the year in which they were granted. The number itself is sufficient indication.

The Entries

Entries employing a double-ended C hook, with a screw to "mouse" the chain, were received from **R. E. W. Baker**, **W. Brown** and **D. Rickman**. The only disadvantage we find with this simple solution is that a tool is required, whether it be a screwdriver, tommy bar or spanner. **A. D. Watt** has the same idea for the double-ended hook, but uses a swing

plate to "mouse" the chain, and comes rather close to J. H. Taylor's recent Patent (No. 774,212) (a device for quickly securing the ring in a bull's nose, an operation surely requiring speed and sureness in the device used!). His patent uses a turn buckle at the centre of the double C.

The double-S principle in **W. Jones'** solution is good, but his proportions are poor and he is anticipated by the following patents: J. Gudgin (Pat. No. 22,369—1893) and P. Roach (Patent No. 21,339—1893). **A. Johnys'** entry is better proportioned, but he has loose parts and a spanner must be used.

H. Hughes sent a most ingenious entry, having no loose parts, which would provide a link almost as strong as the chain itself—an important feature. It is, indeed, this important fact that a chain must be as strong as its weakest link (i.e., the joining shackle) that probably explains why clever shackles are not commonly employed. Most of the shackles seen in our search of the Patent files were merely improved quick-release devices for the pin of the conventional shackle, and intended for the joining of mine cars. Mr. Hughes' entry is unfortunately partly anticipated by that of W. Hodge and J. Pearson (Patent No. 14,088—1893). We would mention that the closing years of the nineteenth century were vintage ones for chain shackle designers!

J. Tindale approached the problem with the assumption that, as the traditional shackle had proved its popularity, it was better to redesign it so that there was less possibility of damage or loss to its component parts. Part 1 is a hot stamping or forging, complete with bolt, and will require no machining other than tumbling or fettling; Part 2 will be similarly made. Part 3 is made on a blanking press with hole, keyway and three outer scallops. Part 3 is assembled to Part 2 and retained and secured from rotation by dimpling into the scallops. To assemble the shackle, Part 2 is pushed on to the bolt of Part 1 by aligning the keyways with the two keys at 90 deg. to each other. The chain can be fed on to the shackle without disconnecting the bolt. The chain, when taut, will constrain the two parts of the shackle to act as one. Should the chain shackle spread apart, as must happen with a slack chain, the second raised key makes the likelihood of the two parts of the shackle coming apart unlikely, as they must be swivelled together for this to happen. This solution appears rugged and simple. Only correct proportioning would ensure it being as strong as a link. It is essentially Mr. Hughes' shackle cut in half, with refinements.

D. C. Wood's entry must, of necessity, be rather larger than a chain link, and so not pass readily over a chain pulley. It is very ingenious, however, and might well be excellent for certain shipboard applications. It appears to be original.

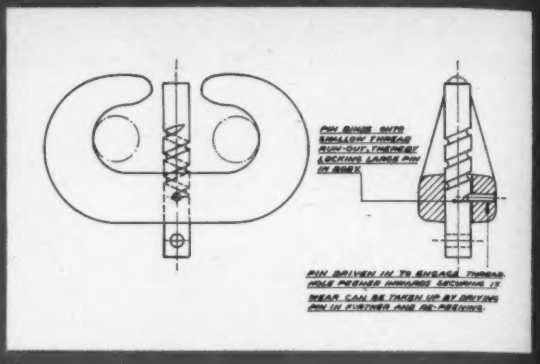
The remaining two entries are extraordinarily simple and neat. **Björn Kristinsson**, of Reykjavik, Iceland, sends a double-C hook entry, the two identical halves being secured by a captive screw. Although J. and U. Thomas produced a double-C shackle in 1906 (Patent No. 11,522), it is differently pivoted. Mr. Kristinsson's shackle seems admirable, particularly in that the screw pin is not in shear, as it appears to be at first sight, but merely holds the two C's together.

J. H. N. Lampard's single-component shackle best answers the requirements of the problem as set, in its simplicity. We cannot absolutely guarantee the thoroughness of our search of the Patent files, but his entry also appears to be original.

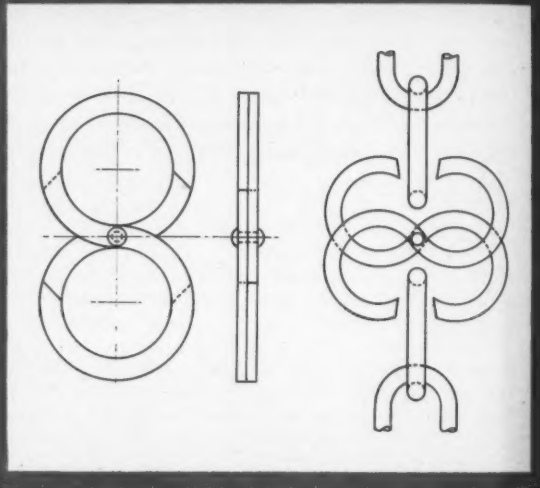
Relevant Patent Numbers

Summarising the entries is difficult, as some that appear plausible on a drawing might not make up so well or be robust. For those interested, we give below relevant Patent numbers on ingenious shackles discovered in our search of the files.

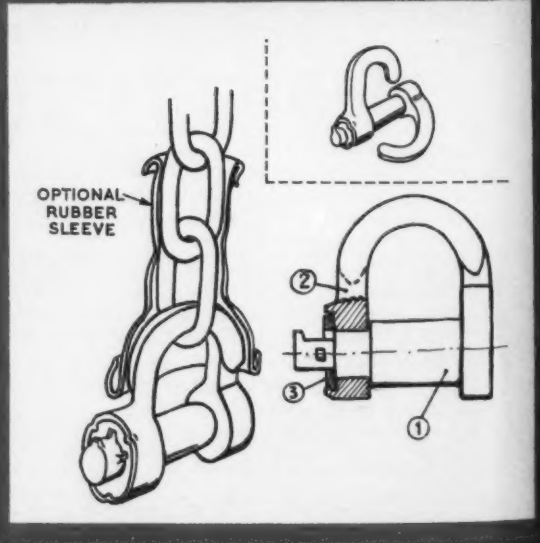
Patent Nos. 825,575; 774,212; 677,224; 675,980; 610,927; 475,107; 418,188; 359,172; 352,930; 11,245 (1907); 11,522 (1906); 1,928 (1895); 7,395 (1894); 22,369 (1893); 21,339 (1893); 14,088 (1893); 9,823 (1883).


PIN BINDS ONTO SHALLOW THREAD RUN-OUT, THEREBY LOCKING LARGE PIN IN BODY
PIN DRIVEN IN TO ENGAGE THREAD HOLE PREVENTS UNWARE SECURING IT
WEAR CAN BE TAKEN UP BY DRIVING PIN IN FURTHER AND RE-PEENING

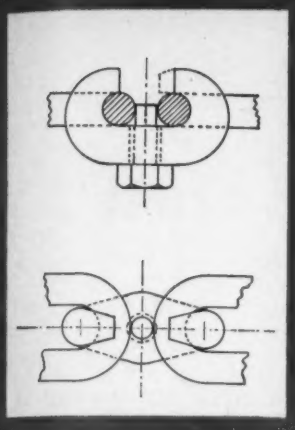
R. E. W. BAKER



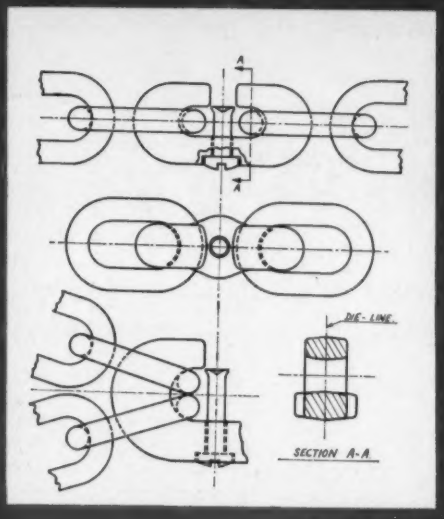
W. JONES



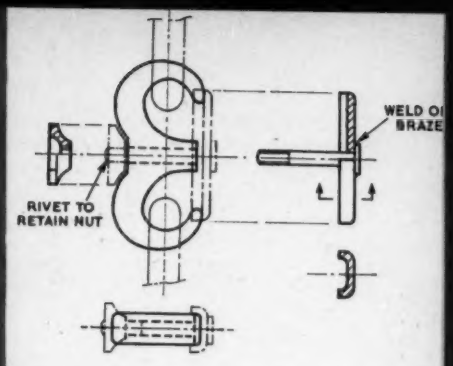
J. TINDALE



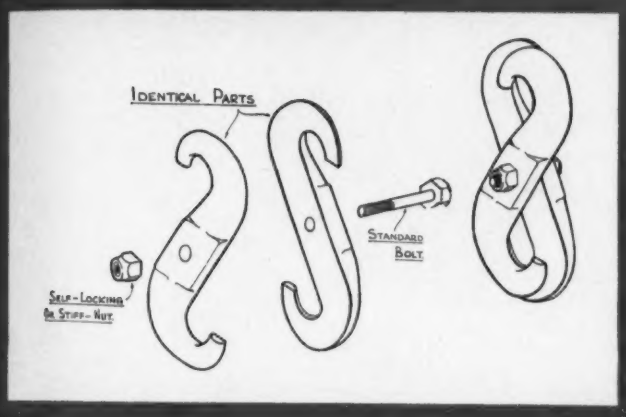
W. BROWN



D. KICKMAN



A. D. WAT



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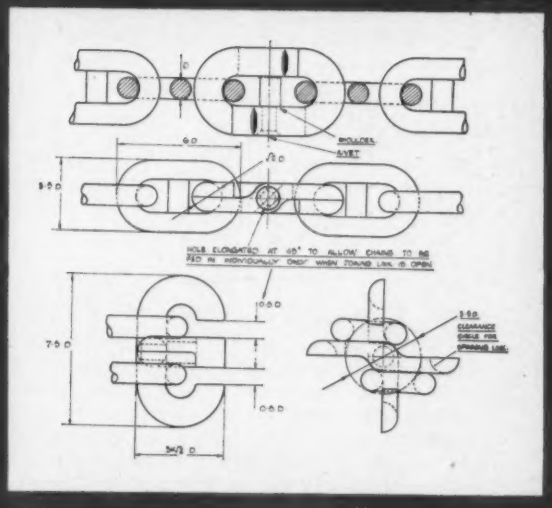

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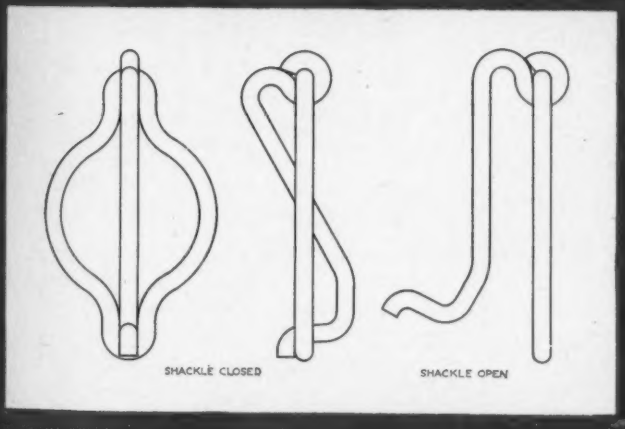

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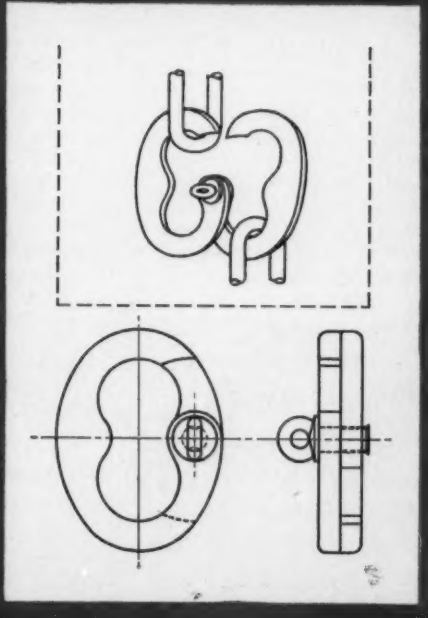
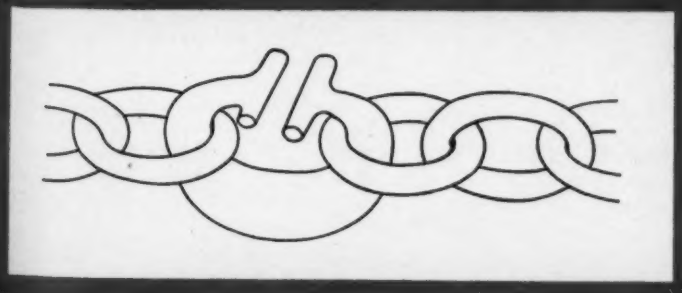


BJÖRN KRISTINSSON



J. H. N. LAMPARD

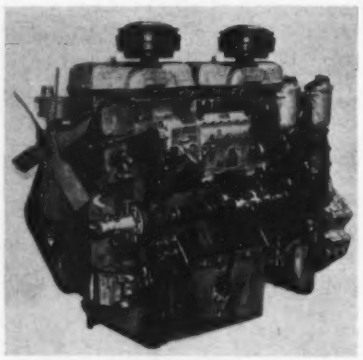
DIESEL ENGINES UP TO 300 B.H.P. : PART 2

Continuation from our November issue of the survey of diesel engines obtainable in the United Kingdom. (To be concluded in the January issue.)

Dennis Bros. Ltd.

The diesel engines produced by this company are for automotive applications, and are all six-cylinder water-cooled in-line engines using wet liners. The 5- and 5½-litre engines have two valves per cylinder, and the 0-6- and 8-litre engines have four, two inlet and two exhaust valves per cylinder—in all models these are operated by push rods from a gear-driven camshaft.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. automotive rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
5-litre Mk. II	6	5·069	—	75/2,000	220/1,200	—
5½-litre Mk. II	6	5·491	—	87/2,000	242/1,200	—
0-6	6	7·585	—	100/1,800	320/1,100	—
8 litre	6	8·025	—	120/1,800	368/1,100	—



8-litre.

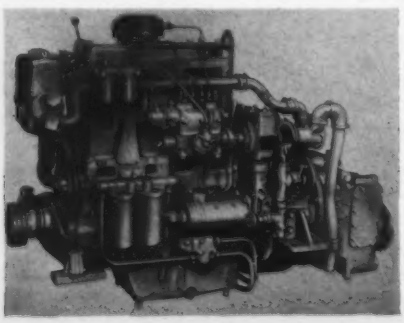
W. H. Dorman & Co. Ltd.

The L series consist of 2-, 3-, 4-, 5-, 6-, and 8-cylinder engines with a power range from 40-200 b.h.p., either normally aspirated or pressure charged. The 3-, 4-, 5- and 6-cylinder engines are available for marine propulsion with an overall power range of 26-132 b.h.p. Wet cylinder liners are used, the bores being hard chromium plated. Overhead valves operated by pushrods from a gear-driven camshaft are incorporated, the inlet valves being masked to promote rotational swirl.

The K type engines are 6-cylinder units, normally aspirated or turbo-charged, and incorporate wet cylinder liners, direct injection and toroidal combustion chambers. The overhead valves are operated by pushrods from a Triplex roller-chain-driven camshaft, the chain adjustment being maintained by an automatic chain tensioner.

In the Q series of engines, the 6-cylinder is a vertical in-line engine, while the 8-cylinder is of a "V" formation, the current development programme including 12-cylinder "V" engines. These engines employ wet liners and overhead valves, operated by pushrods from a gear-driven camshaft. Both K and Q 6-cylinder engines can be supplied as marine propulsion units.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Basic weight (lb.)
2 LB	2	3·2	39·5/1,800	44/2,200	131/1,360	827
3 LB III	3	4·8	58·5/1,800	75/2,200	206/1,400	1,044
4 LB III	4	6·4	77·5/1,800	100/2,200	280/1,400	1,192
5 LB	5	8·0	88·5/1,800	119/2,200	335/1,200	1,568
6 LB III	6	9·6	119/1,800	150/2,200	415/1,300	1,686
6 LC	6	11·34	138/1,800	160/1,800	520/1,100	1,686
6 LCT (turbo-charged)	6	11·34	182/1,800	200/1,800	660/1,150	1,716
8 LB	8	12·8	156/1,800	172/1,800	540/1,100	1,900
6 KUD	6	14·78	166/1,800	183/1,800	630/1,200	3,136
6 KUD (with injection advance device)	6	14·78	180/1,800	198/1,800	630/1,300	3,136
6 KUDT (turbo-charged)	6	14·78	217/1,800	240/1,800	830/1,200	3,136
6 KUF	6	16·08	180/1,800	198/1,800	680/1,100	3,136
6 KUF (with injection advance device)	6	16·08	191/1,800	210/1,800	675/800	3,136
6 QA	6	19·6	238/1,800	262/1,800 (being developed to 300/2,100)	840/1,250	3,450
6 QAT	6	19·6	310/1,800	355/1,800 (being developed to 400/2,100)	1,080/1,200	3,450
8 QVA	8	26·08	315/1,800	350/1,800 (being developed to 385/2,000)	1,100/1,200	4,700
8 QVAT (turbo-charged)	8	26·08	413/1,800	455/1,800 (being developed to 520/2,000	1,440/1,200	4,800
Marine						
6 KUAM	6	13·74	150/1,800	—	83/1,200 (at propeller shaft)	3,700
6 KUDH	6	14·78	160/1,800			3,700
6 KUFM	6	16·08	170/1,700			3,700
6 QAM	6	19·6	230/1,800	252/1,800	730·5/1,200	3,925
6 QASH	6	19·6	300/1,800			3,925
					At propeller shaft	
3 LBM	3	4·7	54·5/1,800	60/1,800	175/1,200	—
4 LBM	4	6·3	75/1,800	82/1,800	234/1,200	
5 LBM	5	8·0	92/1,800	101/1,800	283/1,200	
6 LBM	6	9·5	109/1,800	120/1,800	351/1,200	
6 LCM	6	11·3	132/1,800	147/1,800	428·4/1,000	



4 LBM Marine.

Enfield Industrial Engines Ltd.

In the 85 series the H.O.2 is a twin-cylinder air-cooled, horizontally-opposed engine, using aluminium alloy cylinders with cast-in liners of special iron. Overhead valves are used and operated by pushrods from a chain-driven camshaft; cooling is by a fan integral with the flywheel. The H.O.2/Ind is the agricultural and industrial version of the H.O.2 and is equipped with a fuel tank and exhaust system. The V.S.1 and the V.S.1/Ind (agricultural and industrial version) are single-cylinder motors of similar design to the opposed twin engines. The M.V.S.1 and the M.H.O.2, likewise, are the marine versions of the 85 series.

The Enfield 100 series comprise the V.S.100, a single-cylinder air-cooled engine, the H.O.100, an opposed air-cooled twin, and the V.S.100/Ind and H.O.100/Ind, which are the agricultural and industrial versions, being complete with fuel tank and silencing system. The M.V.S.100 and B.O.T.D. are marine versions complete with reverse gear. The general design of these engines follows that used in the 85 series.

The latest engine to be developed is the Enfield 350, a single-cylinder high-speed air-cooled motor, alternatively available as a marine engine complete with reversing gear.

Type	No. of cylinders	Capacity (cc.)	Cooling	Max. continuous rating (b.h.p./r.p.m.)	Max. rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Net dry weight (lb.)
"85" Series							
Mk. III V.S.1	1	568	A	6·1/1,800	7·3/2,250	20/1,500	224
Mk. III V.S.1/Ind	1	568	A	6·1/1,800	7·3/2,250	20/1 500	284
Mk. IV H.O.2	2	1,135	A	13·4/1,800	16/2,300	46·5/1,200	310
Mk.IV H.O.2/Ind	2	1,135	A	13·4/1,800	16/2,300	46·5/1,200	403
"100" Series							
V.S. 100	1	785	A	9/1,800	11·3/2,200	30/1,500	253
V.S. 100/Ind	1	785	A	9/1,800	11·3/2,200	30/1,500	315
H.O. 100	2	1,570	A	18/1,800	22·6/2,100	62·5/1,500	380
H.O. 100/Ind	2	1,570	A	18/1,800	22·6/2,100	62·5/1,500	450
"350" Series							
350	1	350	A	4·5/2,750	5·25/3,000	150/1,500	200
Marine Versions							
M.350	1	350	A	4·1/2,500	4·75/3,000	150/1,500	250*
M.V.S. 100	1	785	A	8/1,800	9/1,800	30/1,500	400*
Mk.IV M.H.O.2	2	1,135	A	13·4/1,800	16/2,300	46·5/1,200	450*
M.O.T.D	2	1,570	A	16·2/1,800	18/1,800	62·5/1,500	500*
M.V.S. 1	1	568	A	6·1/1,800	7·3/2,250	20/1,500	350*

* Weight complete with reverse gear.

The English Electric Co. Ltd.

The 3K engine is an industrial engine designed primarily for electric power generation and pumping. It is a 3-cylinder water-cooled engine developing a continuous power of 200 b.h.p. at 750 r.p.m. An alternative engine is designed for dual fuel operation.

The RK/V series of diesel engines cover a power range of 165 to 2,504 b.h.p. with in-line or V cylinder formation. The smallest engine is the in-line L2K type which develops a maximum continuous power of 347 b.h.p. at 900 r.p.m.

Fodens Ltd.

The Foden engines are uniflow scavenged two-stroke water-cooled diesels employing the Kadenacy principle. A low-pressure Rootes-type blower feeds air into a common chest from which it is delivered to the cylinders. Wet cylinder liners are used and the twin overhead exhaust valves are operated by short pushrods from a gear-driven camshaft.

Type	No. of cylinders	Capacity (litres)	Continuous rating (b.h.p./r.p.m.)	Max. rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Net dry weight (lb.)
Automotive						
FD.4 Mk. III	4	2·72	88/2,000	100/2,400	244/1,500	933
FD.6 Mk. III	6	4·09	135/2,000	150/2,400	365/1,500	1,100
Marine						
FD.4 Mk. III	4	2·72	80/2,000	90/2,250	230/1,500	1,280*
FD.6 Mk. III	6	4·09	120/2,000	135/2,250	345/1,500	1,659*
FD.12 Mk. III	12	8·18	240/2,000	270/2,250	690/1,500	3,115*

* Inclusive of reverse gearbox.

Ford Motor Co. Ltd.

In the 957 E four-stroke engine the cast-iron cylinder block is fitted with dry type replaceable liners, the combustion chamber being of spherical design to promote swirl. Overhead valves are operated by a gear-driven camshaft through pushrods. The 590 E and 592 E four-stroke engines use wet cylinder liners and direct injection, the combustion chamber being located in the crown of the pistons. Overhead valves are operated by pushrods from a gear-driven camshaft. Marine versions of these engines are also available.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight less accessories (lb.)
957 E	3	2·36	28·2/2,000	31/2,000	92/1,200	590
592 E	4	3·61	57/2,250	63/2,250	158/1,600	690
590 E	6	5·42	86·5/2,250	96/2,250	242/1,500	880

957 E 2·36-litre.

Gardner (Norris, Henty & Gardner Ltd.)

The engine powers quoted in the tables are as set at the works for normal conditions of ambient temperature and altitude for the specific duties indicated.

Adverse climatic or altitude conditions, also conditions of duty, may demand some amendment to the ratings quoted. Conversely, certain applications may permit an engine being set to somewhat higher speeds and powers.

All engines are fitted with in-built centrifugal or plunger-type pumps for circulating cooling water. Fresh water is recommended for all marine engines in preference to sea water cooling and suitable equipment is available for this purpose.

Engines are of the four-stroke cycle design and employ the open cylinder combustion principle with combustion chamber formed in the piston crown. Fuel injection sprayers

Gardner (cont.)

are of exclusive Gardner design and manufacture with multi-hole nozzles. Sprayers are non-adjustable and will operate for very long periods without attention or dismantling.

The L3 engines are fitted with renewable cast-iron wet type cylinder liners, each of these being also fitted with a renewable dry liner having long wearing properties. All other types of Gardner engines are equipped with replacable dry type liners pressed into the cylinder blocks. Inlet and exhaust valves are mounted in the cylinder heads, being operated by pushrods and rockers from renewable cams mounted in pairs on a single camshaft within the main crankcase and driven by Triplex roller chain. Timing of fuel injection is automatically varied with engine speed from idle to maximum r.p.m.

Type	No. of cylinders	Capacity (litres)	Max. rating (b.h.p./r.p.m.) for specific duties	Max. torque (lb. ft./r.p.m.)	Net dry weight (lb.)
Automotive					
4 LK	4	3·8	60/2,100	162/1,100	775
4 LW	4	5·6	75/1,700	237/1,300	1,090
4 HLW (Horizontal)	4	5·6	75/1,700	237/1,300	1,130
5 LW	5	7·0	94/1,700	300/1,300	1,250
5 HLW (Horizontal)	5	7·0	94/1,700	300/1,300	1,295
6 LW	6	8·4	112/1,700	358/1,300	1,440
6 HLW (Horizontal)	6	8·4	112/1,700	358/1,300	1,490
6 LX	6	10·45	150/1,700	485/1,000-1,100	1,583
6 HLX (Horizontal)	6	10·45	150/1,700	485/1,000-1,100	1,730
Rail Traction					
4 LK	4	3·8	60/2,100	162/1,100	775
2 LW	2	2·8	35·5/1,700	113/1,300	—
3 LW	3	4·2	53·5/1,700	170/1,300	—
4 LW	4	5·6	71/1,700	226/1,300	1,090
4 HLW (Horizontal)	4	5·6	71/1,700	226/1,300	1,130
5 LW	5	7·0	89/1,700	285/1,300	1,250
5 HLW (Horizontal)	5	7·0	89/1,700	285/1,300	1,295
6 LW	6	8·4	107/1,700	342/1,300	1,440
6 HLW (Horizontal)	6	8·4	107/1,700	342/1,300	1,490
6 LX	6	10·45	150/1,700	485/1,000-1,100	1,583
6 HLX (Horizontal)	6	10·45	150/1,700	485/1,000-1,100	1,730
4 L 3	4	12·0	102/1,200	488/700	—
5 L 3	5	15·0	128/1,200	610/700	—
6 L 3	6	18·0	153/1,200	733/700	—
8 L 3	8	24·0	204/1,200	978/700	—
Marine Propulsion					
2 LW	2	2·8	28/1,300	—	—
3 LW	3	4·2	42/1,300	—	—
4 LW	4	5·6	56/1,300 to 62/1,500	—	—
5 LW	5	7·0	70/1,300 to 78/1,500	—	—
6 LW	6	8·4	84/1,300 to 94/1,500	—	—
6 LX	6	10·45	110/1,300 to 127/1,500	—	—
3 L 3	3	9·0	57/900	—	—
4 L 3	4	12·0	76/900	—	—
5 L 3	5	15·0	95/900	—	—
6 L 3	6	18·0	114/900	—	—
8 L 3	8	24·0	152/900	—	—
Industrial					
2 LW	2	2·8	29/1,400* 24/1,200	109/1,400	—
3 LW	3	4·2	43/1,400* 36/1,200	162/1,400	—
4 LW	4	5·6	58/1,400* 48/1,200	218/1,300	—
5 LW	5	7·0	72/1,400* 60/1,200	273/1,200	—
6 LW	6	8·4	87/1,400* 72/1,200	328/1,300	—
6 LX	6	10·45	119/1,400* 97/1,200	455/1,050	—
3 L 3	3	9·0	57/900*	—	—
4 L 3	4	12·0	85/1,000* 76/900	463/700	—
5 L 3	5	15·0	106/1,000* 95/900	579/700	—
6 L 3	6	18·0	127/1,000* 114/900	695/700	—
8 L 3	8	24·0	170/1,000* 152/900	927/700	—
1 L 2†	1	1·4	11/1,100	—	—

† For industrial and marine auxiliary duties. * For intermittent duties.

General Motors (R.J.C. Motors & Marine Engines Ltd.)

General Motors Detroit Diesel Division have developed the most comprehensive all-purpose power line of engines from 20 to 1,650 h.p. Using only three cylinder sizes, the family relationship and parts interchangeability for G.M. diesels have been maintained. The small two-cycle diesel engines incorporate the patented G.M. unit fuel injection and uniflow blower scavenging, resulting in more compact, lightweight units.

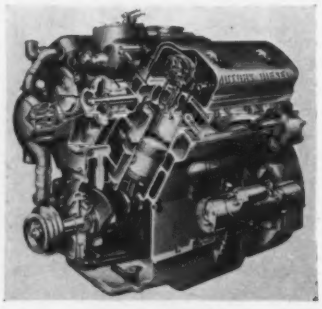
Series 71 engines are based on 71 cu. in. (1,163·5 c.c.) per cylinder displacement, with bore and stroke of 4¼ × 5in. (114 × 127 mm.) and a compression ratio of 17:1. They are manufactured as single-engine in-line units of 2, 3, 4 and 6 cylinders and in V type single engine units of 6, 8, 12 and 16 cylinders. Multi-engine units known as Twins and Quads result from the mounting of either two or four of the single-engine units on a common base, combining the power through clutches and a gearbox to a single power take-off shaft. Twin engines normally consist of two single engine units mounted side by side, although a Tandem Twin, with the engines placed end to end and connected to a gearbox in the centre, is manufactured for marine propulsion.

The series 110 engines comprise a second cylinder size each with a capacity of 110 cu. in. (1,802·6 c.c.). The 6-110 basic engine is conservatively rated at 300 b.h.p. at 2,000 engine r.p.m. As in the 71 series, series 110 engines are available as industrial and vehicular fan-to-flywheel units; radiator-cooled or heat-exchanger cooled industrial power units, with or without bases; and as marine propulsion units. Conceived as the original extension of single-engine G.M. diesel power into a higher horsepower range than that furnished by the 6-71 engine, the 6-110 engine has the same basic design features found in the 71 series. Like the series 71 engines, it is a two-cycle, blower scavenged engine with unit injectors, a fully pressurised lubrication system and adequate thermostatically controlled cooling.

Twin 110 engines are available in side-by-side versions, principally for industrial applications, and in both side-by-side and tandem designs for marine propulsion. Compounding of the engines in the side-by-side Twin 6-110 is accomplished by a high-velocity chain drive instead of gears, which permits a wide range of speed reductions.

Among the latest additions are the 2-, 3- and 4-cylinder in-line and 6V series 53 engines. With a capacity of 53 cu. in. (868.5 c.c.) for each cylinder, these compact, smaller two-cycle diesels have a compression ratio of 17:1, and incorporate all of the latest design features of the 71 series.

Series 53 in-line and 6V-53 engines are available in a variety of models including fan-to-flywheel, industrial power and vehicular engines, base-mounted industrial engines and marine propulsion engines with hydraulically operated reverse and reduction gears.



Series 71.

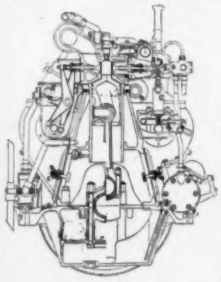
Basic Type	No. of cylinders	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Industrial Engines (Series 53, 71 and 110)					
2055	2	40/1,800	56/2,000	165/1,400	960
3055C	3	72/1,800	96/2,000	270/1,600	1,525
4055C	4	98/1,800	134/2,000	366/1,600	1,780
6055C	6	147/1,800	201/2,000	546/1,600	2,190
4094	4	98/1,800	134/2,000	366/1,600	1,750
6094	6	147/1,800	201/2,000	556/1,600	2,105
3058C	3	72/1,800	96/2,000	270/1,600	1,605
4058C	4	98/1,800	134/2,000	366/1,600	1,770
6058C	6	147/1,800	201/2,000	556/1,600	2,210
3045C	3	67/1,800	90/2,100	261/1,400	1,575
4045C	4	93/1,800	127/2,100	351/1,400	1,750
6045C	6	142/1,800	210/2,100	549/1,400	2,135
3057C	3	72/1,800	96/2,000	270/1,600	1,525
4057C	4	98/1,800	134/2,000	366/1,600	1,780
6057C	6	147/1,800	201/2,000	546/1,600	2,190
Automotive Engines (Series 53, 71 and 110)					
4171	4	—	156/2,300	395/1,600	1,780
3172	3	—	109/2,300	283/1,400	1,525
4172	4	—	156/2,300	395/1,600	1,780
4172E*	4	—	133/2,100	403/1,200	1,780
6172E*	6	—	200/2,100	604/1,200	2,080
3174	3	—	106/2,100	293/1,400	1,525
4174	4	—	156/2,300	395/1,600	1,780
6174	6	—	238/2,300	602/1,600	2,190
4174E*	4	—	145/2,100	403/1,200	1,780
6174E*	6	—	218/2,100	604/1,200	2,080
5047	4	—	130/2,800	273/1,000	1,040
4171E*	4	—	145/2,100	403/1,200	1,550
5067	6V	—	195/2,800	430/1,000	1,340
6171E*	6	—	218/2,100	604/1,200	2,010
7067*	6V	—	218/2,100	604/1,200	1,855
6174	6	—	238/2,300	606/1,400	2,190
7087*	8V	—	290/2,100	805/1,200	2,305
62306 RD LD	6	—	310/2,000	916/1,000	3,260

Basic Type		No. of cylinders	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Industrial Engines with Torqmatic Converter (Series 71 and 110)						
3080		3	—	76/2,000	640 at stall speed	1,635
4080		4	—	104/2,000	1,259 at stall speed	2,100
6080		6	—	167/2,000	1,732 at stall speed	2,610
3081		3	—	76/2,000	640 at stall speed	1,635
4081		4	—	104/2,000	1,259 at stall speed	2,100
6081		6	—	167/2,000	1,732 at stall speed	2,610
62306 RD		6	—	212/1,800	2,780 at stall speed	3,785
Marine Engines (Series 53, 71 and 110)						
Starboard	*Port*					
3-53 RH	3-53 LH	3	62/2,200	86/2,800*	—	1,050
4-53 RH	4-53 LH	4	85/2,200	120/2,800*	—	1,200
6V-71 RH	6V-71 LH	6V	180/2,300	230/2,300*	—	2,570
8V-71 RH	8V-71 LH	8V	228/1,800	308/2,300*	—	3,130
12V-71 RH	12V-71 LH	12V	335/1,800	456/2,300	—	4,485
16V-71 RH	16V-71 LH	16V	445/1,800	607/2,300	—	7,000
3071 C	3072 C	3	68/1,800	110/2,300	—	1,580
4071 C	4072 C	4	95/1,800	151/2,300	—	1,700
6071 A	6072 A	6	147/1,800	235/2,300	—	2,740
6071 E	6072 E	6	170/1,800	—	—	2,740
62206 RD	62206 LB	6	220/1,800	289/2,000*	—	4,235
62207 RD	62207 LB	6	227/1,800	314/2,000	—	4,335
12005 A	12006 A	12	295/1,800	470/2,300	—	5,860
	12007	12	295/1,800	470/2,300	—	6,400
	12003 C	12	295/1,800	470/2,300	—	7,500
	12006	12	440/1,800	578/2,000	—	10,800
	24003	24	590/1,800	893/2,100	—	12,850
Aluminium Marine Engine (Series 71)						
4087	4088	4	—	151/2,300	—	1,920
6087	6088	6	—	235/2,300	—	2,270
6071 B	6072 B	6	—	235/2,300	—	2,270

* Fitted with four valves per cylinder.

Gleniffer Engines Ltd.

The Gleniffer water-cooled marine diesels cover a range of powers from 24 to 160 b.h.p. and are designed for main propulsion systems or for powering self-contained electric generator sets. Wet cylinder liners are used, and horizontally opposed valves open into a spherical combustion chamber. Valve operation is by rockers, which, for the exhaust valve, work direct on the high camshaft. The inlet valve is operated by a short horizontal pull-rod by a rocker from the same camshaft, which is driven by a duplex roller chain. For twin-screw operations the engines may be handed to form a pair.



Section through valve.

Type	No. of cylinders	Capacity (litres)	Normal continuous rating (b.h.p./r.p.m.)	Weight (lb.) with reversing gear less propeller shaft
DB 2	2	3·48	24/1,000	2,576
DB 3	3	5·22	36/1,000	2,940
DB 4	4	6·96	48/1,000	3,220
DB 6	6	10·44	72/1,000	3,950
DH 3	3	12·3	60/900	4,140
DH 4	4	16·4	80/900	4,480
DH 6	6	24·6	120/900	5,750
DH 8	8	32·8	160/900	6,980

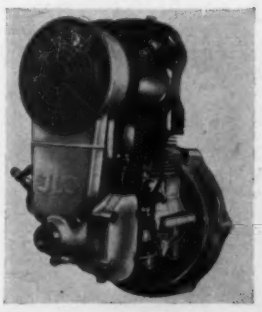
Graymarine (Marine Power (Poole) Ltd.)

The noteworthy feature of these diesels is the air cell type of combustion chamber which, it is claimed, reduces the pressure peaks and permits smoother and quieter operation. The 4-cylinder models are fitted with wet type cylinder liners, the 6-cylinder models being without cylinder liners; all blocks are cast from chrome molybdenum iron alloy. All engines employ overhead valves operated by pushrods from a gear-driven camshaft. These engines are designed for marine use and are complete with transmission gears which are available in various ratios. The cooling system is of the enclosed fresh water type, using a belt-driven centrifugal pump; an outboard type heat exchanger is fitted as standard, with the inboard type heat exchanger as optional.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Four—D 129	4	2·115	23/2,000	30/2,220	83/1,600	656
Four—D 154	4	2·573	24/1,600	30/1,800	100/1,100	1,100
Four—D 277	4	4·538	50/2,000	66/2,200	200/1,000	1,440
Six—D 427	6	6·999	135/2,200	150/2,400	400/1,200	2,510
Six—D 802	6	13·153	157/2,000	190/2,200	490/1,200-1,600	2,900

Industrial Power Units Ltd.

The JLO range of engines are manufactured in Germany and are lightweight, fan-cooled, two-stroke diesels. The 365-c.c. capacity develops 7·0 b.h.p. at 2,500 r.p.m., while the 660-c.c. engine develops 12·0 b.h.p. at 2,000 r.p.m.



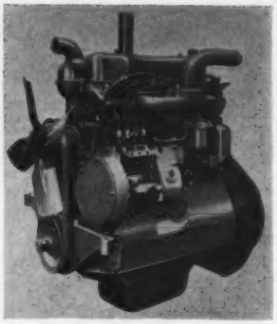
Air-cooled DL 660.

British Polar Engines Ltd. have pointed out that the type No. of their smallest diesel engine is M44I (not M.141, as given on page 696 of the November issue).

International Harvester Company of Great Britain Ltd.

This company designs and manufactures, in England, two models of water-cooled diesel engines. They are the BD-144 and BD-264 engines, both of which have overhead valves operated by pushrods from a gear-driven camshaft. The BD-144 is a robust engine designed specifically for the tough treatment that farm tractors receive, and is fitted to both agricultural and industrial versions of the 30 h.p. B-250 and 35 h.p. B-275 tractors. A prolonged, steady power stroke and smooth running are assured by the through-type combustion chambers and pintle nozzle injectors, the latter being less prone to blockage than the multi-spray type injectors. Electric glow plugs in the combustion chamber ensure quick starting from cold.

The D-264 is also British made, and quick starting at low temperatures (40 deg. of frost) is possible, again through the use of glow plugs in the precombustion chamber.



Automotive BD-264.

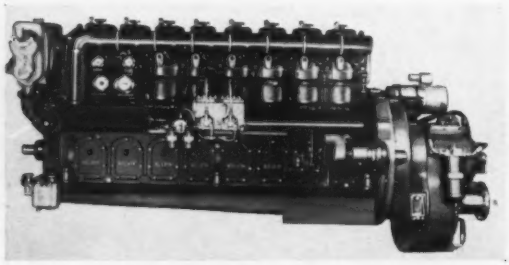
Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
BD-144	4	2·36	27·8/1,750	30·5/1,750	97·5/1,500	554
BD-144-A	4	2·36	31·8/1,875	35/1,875	104/1,400	554
BD-264	4	4·33	50/1,500	55/1,500	200/1,100	1,001

Kelvin (The Bergius Co. Ltd.)

The Kelvin diesel marine engines produced by this company range from 10 h.p. up to 240 h.p., and are designated models J, K, P and T. All these models are of the four-stroke cycle type and are fitted with directly attached reverse, or, in the case of models KR and T, reverse/reduction gears. The model KR reverse/reduction gear incorporates a 2:1 ratio reduction; the model T reverse/reduction gear can incorporate either 1:1, 2:1, 2½:1 or 3½:1 ratio gears.

In addition to the above mentioned, the models P and K can be fitted with 2:1 ratio reduction gears, which mount directly on to the existing reverse gear.

Direct injection type of combustion system is used with overhead valves operated from a gear-driven camshaft. Models J and K use dry cylinder liners and models P and T have wet type liners.



240-b.h.p. T8.

Basic types	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. rating (b.h.p./r.p.m.)	Max. torque (lb. ft.)	Dry weight (lb.)
P2	2	1·06	10/1,500	10/1,500	35	605
P2R	2	1·06	10/1,500	10/1,500	35	646
P4	4	2·13	20/1,500	20/1,500	70	750
P4R	4	2·13	20/1,500	20/1,500	70	791
J2	2	2·89	22/1,000	22/1,000	115·5	1,354
J3	3	4·34	33/1,000	33/1,000	173·25	1,610
J4	4	5·8	44/1,000	44/1,000	231	1,866
K2	2	8·14	44/750	44/750	308	3,168
K3	3	12·21	66/750	66/750	462	3,735
K3SR	3	12·21	66/750	66/750	462	4,100
K4	4	16·29	88/750	88/750	616	4,350
K4SR	4	16·29	88/750	88/750	616	4,800
KR4	4	16·29	88/750	88/750	616	5,500
KR6	6	24·43	132/750	132/750	924	6,777
T4	4	15·49	120/1,000	120/1,000	630	5,600
T6	6	23·23	180/1,000	180/1,000	945	6,720
T8	8	30·97	240/1,000	240/1,000	1,260	7,840

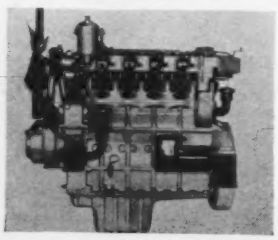
Kirloskar (Marchant Engineering Ltd.)

These engines are primarily for industrial and marine use, and are compression-ignition, four-stroke engines using an open type combustion chamber in the crown of the pistons. Hand starting is employed, and Models B2, B4 and 1M11 X11 have removable wet cylinder liners.

Type	No. of cylinders	Capacity (cc.)	Cooling	Max. continuous rating (b.h.p./r.p.m.)	Net dry weight (lb.)
AA 1	1	553	W	5/1,500	370
AA 2	1	1,106	W	10/1,500	—
AV 1	1	553	W	5/1,500	390
AVA 1	1	553	A	5/1,500	—
AV 1 (Marine)	1	553	W	6/1,800	487
AVA 2	1	1,106	A	10/1,800	—
1M11 X 11	1	1,045	W	10/1,500	475
B2 series II	2	2,090	W	20/1,500	907
AV 2	2	1,106	W	10/1,500	507
B 4	4	4,180	W	40/1,500	1,491

Krupp (J.M.J. Maus Ltd.)

The Krupp water-cooled diesel engine operates on the two-stroke cycle with uniflow scavenging by means of a belt-driven Rootes blower. Multiple overhead exhaust valves are used and are operated by short pushrods from a high gear-driven camshaft. Wet cylinder liners are used.



D 433 3·25-litre.

Type	No. of cylinders	Capacity (litres)	Max. continuous (stationary engine) (b.h.p./r.p.m.)	Max. power automotive engine (b.h.p./r.p.m.) (S.A.E. rating)	Max. torque (lb. ft./r.p.m.)	Weight (lb.)
D 433	4	3·25	105/2,400	132/2,500	274/1,400	830
D 344	3	4·36	115/1,500	138/1,950	368/1,250	1,370
D 447	4	4·75	120/2,000	160/2,400	362/1,450	1,600
D 459	4	5·81	155/1,800	183/1,900	505/1,250	1,750
D 573	5	7·27	187/1,800	220/1,900	592/1,250	2,020
D 710	7	10·17	264/1,800	310/1,850	870/1,200	2,800

Larsson Wilson Marine Motor Co. Ltd.

These water-cooled marine engines are of the same bore and stroke, and employ an open-type combustion chamber in the crown of the piston. Overhead valves are used, and are operated from a gear-driven camshaft. Weights given are for engine complete with reverse/reduction gearbox.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. in./r.p.m.)	Dry weight (lb.)
G.62	6	9·84	105/1,200	105/1,200	1,600/1,200	2,755
G.41	4	6·56	90/1,200	90/1,200	1,600/1,200	2,425–2,443

R. A. Lister & Co. Ltd.

Types LD and SL are air-cooled four-stroke diesels with pintle-type injection nozzles and a combustion chamber within the crown of the piston. Various forms of power take-off are available and reverse rotating engines may be supplied.

Types HA and HB cover a range of 2-, 3- and 6-cylinder engines. The 2- and 3- cylinder models are of the same basic construction and draw the cooling air from a fan integral with the flywheel, whilst the HA6 and HB6 have twin axial flow fans separately driven from the engine. The HA engine operates up to a speed of 1,800 r.p.m., the HB extending to 2,000 r.p.m.

The water-cooled series are either single- or twin-cylinder models arranged for tank or radiator cooling. The engines are of the four-stroke type with chrome-hardened cylinder blocks.

The JP series comprise 2-, 3-, 4- and 6-cylinder models of four-stroke engines using overhead valves and cylinder liners. The valves are operated by pushrods from a driven camshaft.

The JK series are of similar design to the JP series but have a higher operating speed. The FR series incorporates a dual combustion chamber giving a high compression ratio for easy starting and a lower ratio for normal running, each cylinder having a separate injection pump. The engines are four-stroke units with overhead valves and chrome-hardened cylinder liners.

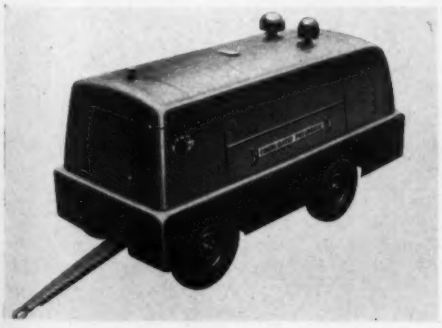
The Lister Blackstone water-cooled units are the heaviest and most powerful engines in the Lister range. The overhead valves are operated by pushrods from a gear-driven camshaft, the cylinders being fitted with wet liners. Compressed air starting is standard equipment, but engines may be arranged for electric starting. EV and ER are naturally aspirated engines, turbo-charged versions being the EVS and ERS. The ES and ESS engines are developed from the EV and ER ranged to run at higher speeds. 4-, 6- 8-, 12- and 16-cylinder engines, both naturally aspirated and turbo-charged, can be supplied as dual-fuel engines and are classed as EVDF and ERDF.

Type	Cooling	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Intermittent power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
LD 1	A	1	0·405	3½/1,800	3·85/1,800	11·6/1,550	236
LD 2	A	2	0·811	7/1,800	7·75/1,800	23·2/1,540	416
SL 1	A	1	0·455	4½/2,000	5·2/2,000	13·94/1,300	236
SL 2	A	2	0·910	9½/2,000	10·5/2,000	27·8/1,300	416
SL 3	A	3	1·365	12½/1,800	14·3/1,800	41·2/1,100	476
SL 4	A	4	1·820	17/1,800	20·9/2,000	54·88/2,000	530
HA 2	A	2	1·850	22/1,800	23·2/1,800	75/1,300	610
HA 3	A	3	2·775	33/1,800	36·2/1,800	112·5/1,210	810
HA 6	A	6	5·550	66/1,800	72·5/1,800	224·2/1,250	1,200
HB 2	A	2	1·850	24/2,000	26·4/2,000	75/1,300	620
HB 3	A	3	2·775	36/2,000	39·5/2,000	112·5/1,210	790
HB 6	A	6	5·550	72/2,000	79/2,000	224·2/1,250	1,200
VA	A	1	1·435	7½/850	8·25/850	46·4/650	735
3½/1	W	1	0·993	3½/650	3·85/650	—	672
6/1	W	1	1·435	6/650	6·6/650	—	672
8/1	W	1	1·435	8/850	8·8/850	—	740
12/2	W	2	2·870	12/650	13·2/650	—	994
16/2	W	2	2·870	16/850	17·6/850	—	1,062
JP 2	W	2	2·870	23/1,200	25/1,200	103/1,000	1,520
JP 3	W	3	4·305	35/1,200	38/1,200	155·5/1,000	1,970
JP 4	W	4	5·740	46/1,200	50·4/1,200	206/1,000	2,300
JP 6/6	W	6	8·610	70/1,200	77/1,200	311/1,000	3,040
JK 2	W	2	2·870	31/1,500	34/1,500	100/1,000	1,520
JK 3	W	3	4·305	46·5/1,500	51/1,500	162/1,250	1,970
JK 4	W	4	5·740	62/1,500	68/1,500	218/1,225	2,300
JK 6	W	6	8·610	90/1,500	99/1,150	325/1,500	3,040
FR 1	W	1	0·814	9/1,800	9·9/1,800	28·2/1,475	770
FR 2	W	2	1·628	18/1,800	19/1,800	56·25/1,460	940
FR 3	W	3	2·442	27/1,800	29·7/1,800	84/1,475	1,110
FR 4	W	4	3·256	36/1,800	39·6/1,800	112·2/1,460	1,330
FR 6	W	6	4·884	54/1,800	59·4/1,800	168/1,460	1,720
*Lister-Blackstone Engines**							
ER 2		2	24·2	112/750	123/750	788	6,356
ER 3		3	36·3	168/750	185/750	1,182	7,756
ER 4		4	48·45	225/750	247/750	1,577	9,184
ER 5		5	60·5	280/750	308/750	1,970	11,536
ER 6		6	72·7	337/750	370/750	2,365	12,824
ER 8		8	96·8	450/750	495/750	3,153	16,352
ERS 4		4	48·45	330/750	363/750	2,313	9,604
ERS 6		6	72·7	495/750	545/750	3,470	13,440
ERS 8		8	96·8	660/750	726/750	4,627	17,612
EV 2		2	24·2	90/600	99/600	788	6,580
EV 3		3	36·3	135/600	149/600	1,182	8,092
EV 4		4	48·45	180/600	198/600	1,577	9,408
EV 5		5	60·5	225/600	248/600	1,971	11,872
EV 6		6	72·7	270/600	297/600	2,365	13,300
EV 8		8	96·8	360/600	396/600	3,153	16,912
EVS 4		4	48·45	264/600	290/600	2,313	9,821
EVS 6		6	72·7	396/600	436/600	3,470	13,979
EVS 8		8	96·8	528/600	581/600	4,627	18,144
ES 2		2	24·2	135/900	148/900	788	6,356
ES 3		3	36·3	202/900	222/900	1,182	7,756
ES 4		4	48·45	270/900	297/900	1,577	9,184
ES 5		5	60·5	337/900	371/900	1,971	11,536
ES 6		6	72·7	405/900	445/900	2,365	12,824
ES 8		8	96·8	540/900	594/900	3,153	16,352
ESS 4		4	48·45	400/900	440/900	2,333	9,604
ESS 6		6	72·7	600/900	660/900	3,500	13,440
ESS 8		8	96·8	800/900	880/900	4,664	17,612

* *Torque values are taken at normal engine running speed.*

Leyland Motors Ltd.

These engines are water-cooled four-stroke units with overhead valves and direct fuel injection, the pushrods being operated from a gear-driven camshaft. Dry type cylinder liners are used and a toroidal combustion chamber is machined in the piston crown. These engines are also available in diesel power packs with radiator, power take-off and silencing system. They are also available complete with torque converter drives.



Consolidated Pneumatic compressor powered by a UE.375.

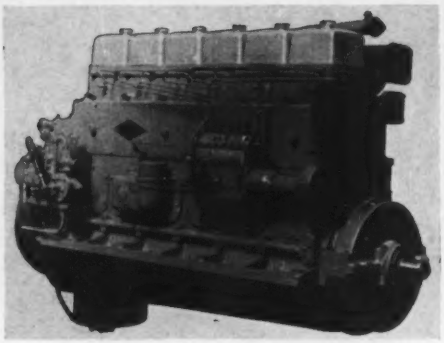
Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
EN/250	4	4·1	—	72/2,200	190/1,300	920
O/350	6	5·75	—	105/2,400	255/1,400	1,170
O/375	6	6·17	—	110/2,400	285/1,100	1,170
O/600	6	9·8	—	125/1,800	400/900	1,640
O/680	6	11·1	—	150/2,000	450/1,100	1,790
O/900	6	15·2	—	230/1,900	728/1,100	2,530
UE.250	4	4·1	55/1,900	71/2,200	190/1,300	920
UE.375	6	6·17	83/2,000	110/2,400	280/1,200	1,250
UE.600	6	9·785	111/1,800	147/2,100	410/1,200	1,900
UE.680	6	11·1	130/1,800	165/2,100	495/1,000	1,925
EN.900	6	15·18	173/1,630	230/1,900	700/1,150	2,580
UE.900 (turbo-charged)	6	15·18	202/1,550	275/1,800	840/1,200	2,640
EU.350	6	5·75	78/2,150	99/2,400	250/1,400	1,210
400-S	6	6·54	—	125/2,400	300/1,600	1,181
E 600	6	9·8	—	140/1,700	438/1,200	1,808
P 680	6	11·1	—	200/2,200	548/1,200	1,840

M.A.N. (North British Locomotive Co. Ltd.)

These engines are of the smaller power range and are primarily for rail traction, marine and industrial application. They are four-stroke engines using the precombustion chamber principle. Wet cylinder liners are employed and the overhead valves are operated by pushrods.

Type	No. of cylinders	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
W3V 17·5/22B	3	90/800	100/900	600/600	3,329
W4V 17·5/22B	4	120/800	140/1,000	808/600	3,858
W5V 17·5/22B	5	150/800	175/1,000	1,010/600	4,894
W6V 17·5/22B	6	225/1,100	240/1,200	1,125/750	5,600
W8V 17·5/22B	8	300/1,100	320/1,200	1,472/750	6,720
W6V 17·5/22BS (supercharged) *	6	330/1,100	345/1,200	1,644/750	6,048
W8V 17·5/22BS (supercharged)	8	440/1,100	460/1,200	2,202/750	7,280

* Completely manufactured by N.B.L.



W6V 17·5/22B.

M.A.N. (W. Wykeham & Co. Ltd.)

The majority of the engines built by Maschinenfabrik Augsburg-Nurnberg A.G. in the low power range from 20 to 300 b.h.p. fall in the category of the M-type engines which are used as stationary units, on road vehicles and in marine craft. The salient feature of the M-type engines is their special combustion process which differs greatly from the conventional combustion process in diesel engines. The formation of the mixture and the process of the combustion depend not only on the physically correct air fuel mixture but also on a chemical process owing to the high air temperature and its influence on the fuel components for mixture and combustion. In the M-type combustion process developed by M.A.N., the fuel is applied to the cool walls of the spherical combustion chamber in the form of a thin film. The fuel film burns off gradually, ensuring an even pressure increase in the engine and a smooth combustion process. The time taken by the fuel for evaporation throttles the formation of the fuel air mixture and the combustion.

The smallest of the M-types is the 2-cylinder D0022 M engine developing approximately 24 h.p. at 2,000 r.p.m. 4- and 6-cylinder versions of this type are also built with outputs of approximately 60 and 90 h.p. The 2-, 4- and 6-cylinder versions are built as in-line engines and the 8-cylinder version as a V-type engine. They are also supplied as horizontal engines. The two newly developed M-types are the D 0836 M engines with a continuous output of 105 h.p. at 2,200 r.p.m. and the D 2146 M engine developing 135 h.p. at 2,000 r.p.m. The M.A.N. range up to 300 b.h.p. ends with the WV 17·5/22 engine, which is an in-line engine of 3 to 8 cylinders used for stationary units (generating sets, compressor sets, boring sets), mobile units (locomotives, railcars, dredgers, road rollers, cranes, construction machinery) and also as marine diesels.

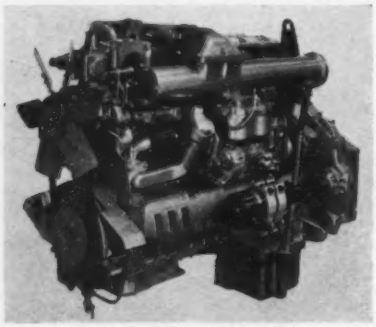
Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
D 0022 M	2	1·96	22/1,800	no overload	64/1,800	736
D 0024 M	4	3·93	54/2,200	no overload	129/1,200	1,014
D 0026 M	6	5·89	80/2,200	no overload	191/2,200	1,136
D 1246 M	6	8·28	105/2,000	no overload	276/2,000	1,621
D 1548 M	8	11·64	150/2,000	no overload	394/2,000	2,090
D 1548 MT (supercharged)	8	11·64	180/2,000	no overload	473/2,000	2,344
WV 17·5/22A	3	15·9	90/800	100/900	583/900	4,542
	4	21·2	120/800	140/1,000	735/1,000	5,182
	5	26·5	150/800	175/1,000	919/1,000	6,240
	6	31·8	210/1,000	240/1,200	1,050/1,200	6,328
	8	42·4	280/1,000	320/1,200	1,400/1,200	7,541
WV.17·5/22M.A. (supercharged)	6	31·8	310/1,000	345/1,200	1,509/1,200	6,990
	8	42·4	415/1,000	460/1,200	2,013/1,200	8,203

Meadows (Henry Meadows Ltd.)

All engines are four-stroke direct injection, with a toroidal combustion space in the piston crown. Overhead valves are operated by pushrods from a gear-driven camshaft, the inlet valves being masked to promote turbulence.

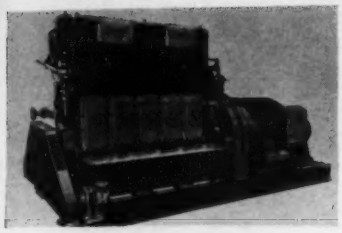
The 6D970 and 970S engines are fitted with wet cylinder liners, and have two inlet and two exhaust valves per cylinder. 4D330 and 6D500 are fitted with wet liners, and have one inlet and one exhaust valve per cylinder. The 6DS630, 6D630 and 4D420 are fitted with dry cylinder liners, and have one inlet and one exhaust valve per cylinder.

The pressure-charged 6DS630 and 6DS970 are fitted with a Holset turbocharger. The marine applications are designed for closed-circuit fresh water cooling, with a sea-cooled heat exchanger. DJ industrial engines can also be supplied in the form of self-contained power mules.



6D630 turbo-charged.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Marine						
6 DM 970	6	15·9	162/1,800	—	—	3,700
6 DMS 970 (turbo-charged)	6	15·9	215/1,800	—	—	3,780
4 DM 330	4	5·43	72/3,000	—		1,300 (with reverse gear)
6 DM 630	6	10·35	111/1,800	—		2,910 (with reverse gear)
Automotive						
4 DC 330	4	5·43	—	100/2,400	250/1,400	1,048
4 HDC 330 (horizontal)	4	5·43	—	100/2,400	250/1,400	1,048
4 DC 420	4	6·9	—	97/2,000	290/1,000	1,570
6 DC 500	6	8·14	—	150/2,500	360/1,500	1,600
6 HDC 500 (horizontal)	6	8·14	—	150/2,500	346/1,500	1,650
6 DC 630	6	10·35	—	145/2,000	430/1,200	1,940
6 DCS 630	6	10·35	—	200/2,000	568/1,450	2,000
6 DC 970	6	15·9	—	200/1,800	615/1,150	3,550
6 DCS 970	6	15·9	—	270/1,800	855/1,250	3,720
Industrial					*Max. torque on continuous rating*	*Less electrics*
4 DJ 420	4	6·9	79/1,800	—	250/1,100	1,480
6 DJ 630	6	10·35	110/1,800	—	365/1,100	1,790
6 DJ 500	6	8·14	97/1,800	—	295/1,350	1,510
4 DJ 330	4	5·43	70/2,000	—	195/1,400	970
6 DJS 630	6	10·35	150/1,800	—	455/1,500	1,900
6 DJ 970	6	15·9	162/1,800	—	560/1,000	3,500
6 DJS 970	6	15.9	250/1,800	—	800/1,250	3,560



TL 5.

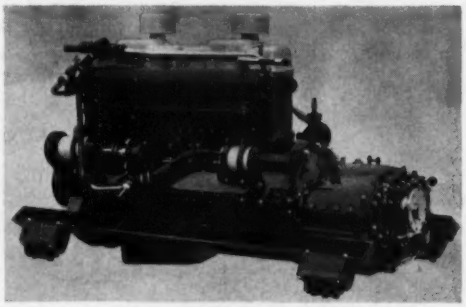
Type	No. of cylinders	Max. continuous rating (b.h.p./r.p.m.)	
Marine (Auxiliary), Industrial and Traction			
TL 3	3	157/600	
TL 4	4	210/600	
TL 5	5	262/600	
TL 6	6	315/600	
TLS 6	6	405/600	
Marine (Main)			
TL 3	3	141/600	Non-reversing engine with reverse reduction gear
TL 4	4	188/600	
TL 5	5	235/600	
TL 6	6	282/600	
TLS 6 (turbo-charged)	6	366/600	
TL 6	6	282/600	Direct reversing engine with reduction gear
TLS 6	6	366/600	
TL 6	6	282/600	Direct reversing without gear-box
TLS 6	6	366/600	

Mirrlees, Bickerton & Day Ltd.

The smallest engines made by this company are the TL series, and are suitable for marine (main propulsion or auxiliaries), rail traction and industrial applications. The basic engine is similar for all applications and is a four-stroke direct-injection engine using wet cylinder liners. The TLS 6 model uses a Buchi type of exhaust gas turbo-charger.

Mercedes-Benz (Great Britain) Ltd.

The following table covers the range of diesel engines up to approximately 300 b.h.p. The Mercedes-Benz engines are all fresh-water-cooled four-stroke engines with overhead valves operated by pushrods from a gear-driven camshaft. Wet type removable liners are used on the M and MB ranges and dry type liners are used on the OM range. The combustion chamber is of the prechamber type. These versatile engines are suitable for automotive, marine, rail traction and industrial applications.



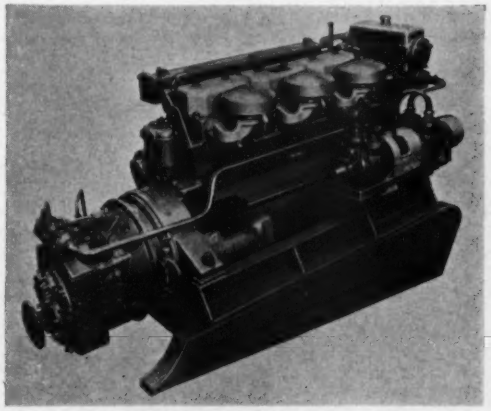
OM 315 8·27-litre.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
M 202 B	2	6·47	49·3/1,200	54·2/1,200	267/850	1,590
M 203 B	3	9·7	85·7/1,200	94·5/1,200	420/950	2,160
M 204 B	4	12·93	113/1,200	124/1,200	556/1,000	2,715
OM 636	4	1·77	31·5/3,000	34·5/3,000	61·5/1,900	400
OM 312	6	4·58	69/2,400	76/2,400	180/1,500	800
OM 326	6	10·81	138/1,800	152·5/1,800	382/1,200	1,740
OM 321	6	5·1	83·8/2,600	92 5/2,600	210/1,800	782
OM 315	6	8·27	110·5/1,800	122/1,800	382/1,250	1,775
MB 846 A	6	20·16	222/1,500	248/1,500	880/1,000	4,066
MB 846 B (horizontal)	6	20·16	222/1,500	248/1,500	880/1,000	4,200
MB 846 Ab (supercharged)	6	20·16	286/1,500	315/1,500	1,140/1,050	4,298
MB 846 Bb (supercharged horizontal)	6	20·16	286/1,500	315/1,500	1,140/1,050	4,640
MB 846 Ac (high super-charged)	6		For special applications; outputs on request.			
MB 846 Ad (high super-charging and inter-cooling)	6					

The National Gas-Oil Engine Co. Ltd.

The LE and LES engines from the lower power range of National diesel engines are suitable for many industrial and marine applications. The engines employ wet cylinder liners and the overhead valves are operated by pushrods from a gear-driven camshaft. The direct-injection combustion principle is employed.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
LE 4	4	9·77	120/1,800	132/1,800	440/1,100	2,550
LE 6	6	14·67	185/1,800	203/1,800	660/1,200	3,400
LES 6 (turbo-charged) *Marine*	6	14·67	240/1,800	264/1,800	850/1,300	3,550 (with electric starting and gearbox)
			(s.h.p./r.p.m.)			
LE 4M	4	9·77	113/1,800			3,900
LE 6M	6	14·67	174/1,800			4,900
LES 6M (turbo-charged)	6	14·67	225/1,800			5,750



Six-cylinder marine.

Newage B.M.C. (Newage (Manchester) Ltd.)

These engines are the industrial versions of the standard B.M.C. range of diesels. Except for the 2·2-litre, which has dry cylinder liners, the engines have wet liners and direct injection. The 2·2-litre employs a Ricardo Comet combustion chamber. These engines are also available as a power pack, complete with radiator, fuel tank, silencing system and power take-off.

Type and Capacity (litres)	No. of cylinders	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
2·2	4	28/2,000	33/2,000	88/2,000	680
2·55	3	32/2,000	38/2,000	109/1,600	672
3·4	4	42/2,000	55/2,000	150/1,410	760
5·1	6	62·5/2,000	82/2,000	225/1,400	860

Paxman (Davey, Paxman & Co. Ltd.)

In this survey data have been restricted to engines with outputs up to 450 b.h.p., but details of engines above this power are available from the manufacturers. Recent additions to the Paxman range, are the new Vega (YGA) air-cooled engines and the compact, lightweight (6·5-7·0 lb./b.h.p.) Ventura (YJ) water-cooled engine.

Specific design features of the Paxman engines include a closed-type cooling system with integral engine-driven centrifugal water pumps, and for air-cooled engines a high efficiency axial flow fan, chain driven from the crankshaft.

The crankcase is cast-iron with integral ribbing, the upper surface carrying the cylinder blocks arranged in two banks. The water-cooled blocks are cast-iron with hardened and tempered liners (RPH engines) or wet liners (YHX engines).

The valve gear consists of one inlet and one exhaust valve per cylinder with stellite-faced seats closing on hardened valve inserts in heads (RPH and YGA engines); two inlet and exhaust valves are fitted to other engines. Valves are actuated by pushrods from a central camshaft. Maximum accessibility is assured, since the engines are built up from a series of self-contained, easily-handled sub-assemblies. This enables servicing to be rapidly carried out, especially when a service exchange system is in force. Moreover, large crankcase doors facilitate the removal of pistons, connecting rods and bearings. A modern quality control system ensures strict interchangeability of complete units and all components, thus dispensing with hand fitting.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.) cont. rating	Dry weight (lb.)
4RPH	4	19·56	160/1,500	176/1,500	670/950	5,350
4RPHX	4	19·56	200/1,500	220/1,500	740/1,000	5,400
6RPH	6	29·33	274/1,500	301/1,500	1,090/1,000	6,400
6RPHX	6	29·33	304/1,500	334/1,500	1,180/1,000	6,500
8RPH	8	39·00	366/1,500	402/1,500	1,420/900	7,600
8RPHX	8	39·00	406/1,500	446/1,500	1,570/850	7,700
6YHX	6	29·33	400/1,500	440/1,500	1,590/850	6,585
6ZH	6	29·33	300/1,500	330/1,500	1,280/850	5,300
6ZHX	6	29·33	410/1,500	450/1,500	1,660/800	5,400
8YGA	8	24·40	265/1,800	310/2,100*	820/1,350	3,475
8YGAX	8	24·40	345/1,800	405/2,100*	1,150/1,550	3,575

In the above table, X in the type designation denotes pressure-charged engine (Holset air cooled turbo-blower).
ZH denotes flat (horizontal) engine suitable for mounting under the floor of rail cars, but can be used for other applications where overall height is restricted.
*All ratings are in accordance with British Standard 649:1958, with the exception of those marked *, which are for automotive applications only. For marine propulsion applications, the standard marine output at the gearbox output coupling is the continuous rating less 7½ per cent for reverse/reduction and 4½ per cent for reduction gearboxes.*

Pelapone Ltd.

These engines are designed for industrial applications and for marine propulsion units. The engines are four-cycle types, cold starting and using a combustion system based on the Richardo Whirlpool swirl chamber in the cylinder head. Dry replaceable cylinder liners are used and the overhead valve gear is operated by pushrods from a gear-driven camshaft.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Model S1	1	1·52	14/1,500	15·4/1,500	63/1,000	952
Model S2	2	3·04	29/1,500	32/1,500	126/1,050	1,288
Model S3	3	4·56	43/1,500	47·3/1,500	189/950	1,680
Model S4	4	6·08	57·5/1,500	63/1,500	254/1,050	1,908
Model S6	6	9·12	87/1,500	95/1,500	376/1,050	2,530
Model 61	1	0·79	7/1,500	7·7/1,500	31/1,000	672

Perkins Engines Ltd.

The current range of Perkins diesel engines has been designed basically for industrial, agricultural and marine duties, where robust construction and easy maintenance are necessary, and as power units for automobiles, trucks and buses, where engine compactness, light weight and flexibility of performance over a wide speed range are essential. The engines listed are all four-stroke, water-cooled, normally-aspirated engines, with straight, in-line cylinder arrangement. All are vertically arranged, with the exception of the C.305 type, which is a horizontal unit inclined at 24 deg.

The cylinder blocks and crankcases are one-piece castings in high-grade iron, and the cylinder heads are also cast iron. There are two overhead valves per cylinder operating in cast-iron guides, two springs being used for each valve. Other main features are as follows:

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.) (bare engine)
Automotive						
Four 99 (V) / Four 99 (C)	4	1·62	—	48/4,000	73/2,250	320
P3/144 (V)	3	2·36	—	41/2,400	100/1,400	398
Six 354 (V)	6	5·8	—	112/2,800	260/1,450	836
Six 305 (V)	6	5·0	—	89/2,600	218/1,250-1,500	684
Four 203 (V)	4	3·33	—	63/2,600	147/1,350	477
Agricultural						
Four 99 (TA)	4	1·62	—	39/3,000	73/1,900	330
P3/144 (TA)	3	2·36	—	38/2,250	100/1,000	444
Four 203 (TA)	4	3·33	—	57/2,250	151/1,350	477
Six 288 (TA)	6	4·73	—	76/2,000	208/1,400	702
Four 270 (TA)	4	4·42	—	62/2,000	190/1,000	680
Six 354	6	5·8	—	107/2·400	266/1,300	1,050
Industrial Engine						
P3/144 (I)	3	2·36	33/2,000†	41/2,000	101/1,400	456
Four 203 (I)	4	3·33	47/2,000	60/2,400	151/1,350	477
Six 305 (I)	6	5·0	71/2,000	87/2,400	218/1,250-1,500	704
R6 (I) Mk 2	6	5·56	69/2,000	102/2,400	240/1,600	904
S6 (I)	6	7·39	105/2,000	123/2,100	318/1,600	1,100
Four 270 (I)	4	4·42	57/2,000	62/2,000	190/1,000	722
Four 99 (I)	4	1·62	34/3,000	42/3,600	73/2,250	330
Marine			Max. Cont. s.h.p./r.p.m.	Max. Intermittent s.h.p./r.p.m.		Wt. with accessories
Four 99 (M)	4	1·62	33/3,000	40/3,600	—	495*
P3/144 (M)	3	2·36	30/2,000	37/2,250	—	1,002*
Six 305 (M)	6	5·0	69/2,000	84/2,400	—	1,040*
Four 270 (M)	4	4·42	58/2,000	—	—	1,150*
S6 (M)	6	7·39	100/2,000	120/2,100	—	1,350*

* *With direct drive and reverse gearbox.*
† *Industrial continuous ratings are to BS 649:1958 unless otherwise stated.*

Engine Type	Combustion system	Cylinder liner type	Timing drive	No. of main bearings
Four 99	H Chamber (pre-combustion)	Cast iron, "wet"	Gear	3
P3/144	Perkins (pre-combustion chamber)	Cast iron, "dry"	Gear	4
Four 203	Perkins	Steel, chrome-plated, "dry"	Gear	5
Four 270	Direct injection Perkins	Cast iron, "wet"	Gear	3
Six 305 and C.305		Steel, chrome plated, "dry"	Chain	7
R6 Mk.2	Perkins	Cast iron, "dry"	Chain	7
Six 354	Direct injection Perkins	Cast iron, "Dry"	Gear	7
S6		Cast iron, "dry"	Chain	7

Petters Ltd.

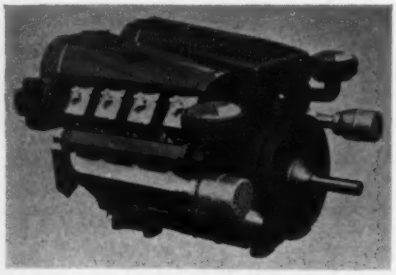
Petter diesels cover a range from 1½ to 108 b.h.p. Features common to all units are overhead valves, four-stroke cycle operation, combustion chambers formed in the piston crowns, direct injection and easy starting. All water-cooled units have removable wet cylinder liners.

The engines are vertical 1-, 2-, 3- or 4-cylinder units except for the two largest air-cooled types, the PDV's, which are of V-form.

A PAZ1 1½ to 3-b.h.p. single-cyinder engine is the smallest diesel in the Petter air-cooled range, which includes AVA and PH singles and twins of 3 to 16·4 b.h.p., PC 1- to 4-cylinder types of 3·25 to 20 b.h.p., PD units with 2 to 4 cylinders of 16 to 54 b.p.h., AS 2- to 4-cylinder types of 6·5 to 33 b.h.p., PDV6 and PDV8 of 54 to 108 b.h.p. The water-cooled range of 3 to 48 b.h.p. includes AV, PHW and B units with 1 to 4 cylinders.

Variations of power take-off and starting arrangements are offered to suit very widely differing applications for contractors' plant, industrial and agricultural machines and marine auxiliaries.

Air-cooled and water-cooled marine propulsion units of 3 to 104 b.h.p. and 3 to 48 b.h.p. respectively are available, and have a choice of drive arrangements.



PDV8 air-cooled.

Type	No. of cylinders	Cooling	Capacity (cc.)	Peak continuous rating (b.h.p./r.p.m.)	Peak intermittent rating (b.h.p./r.p.m.)	Maximum torque (lb. ft./r.p.m.)	Dry weight (lb.)
Industrial and General Purpose							
PAZ1	1	A	348	3/1,800	3·3/1,800	11·3/1,400	236
AVA1	1	A	553	6/1,800	6·6/1,800	22·65/1,600	412
AVA2	2	A	1,106	12/1,800	13·2/1,800	45·3/1,600	558
PH1	1	A	659	8·2/2,000	9/2,000	28·57/1,700	415
PH2	2	A	1,318	16·4/2,000	18/2,000	57·15/1,700	563
PC1	1	A	348	5/3,000	5·5/3,000	12·24/2,200	243
PC2	2	A	696	10/3,000	11/3,000	25·38/2,200	329
PC3	3	A	1,044	15/3,000	16·5/3,000	38·07/2,200	439
PC4	4	A	1,392	20/3,000	22/3,000	50·76/2,200	503
PD2	2	A	2,257	24/1,800	26·4/1,800	84/1,200	969
PD3	3	A	3,387	36/1,800	39·6/1,800	123/1,400	1,124
PD4	4	A	4,515	54/2,000	59·4/2,000	168/1,500	1,329
PDV6	6	A	6,766	78/1,800	85·8/1,800	257·5/1,200	1,640
PDV8	8	A	9,033	108/2,000	118·8/2,000	362/1,400	2,064
AV1	1	W	553	6/1,800	6·6/1,800	22·65/1,600	390
AV2	2	W	1,106	12/1,800	13·2/1,800	45·3/1,600	545
PH1W	1	W	659	8·2/2,000	9/2,000	28·57/1,700	393
PH2W	2	W	1,318	16·4/2,000	18/2,000	57·15/1,700	551
B2	2	W	2,090	20/1,500	22/1,500	77·5/ Constant	1,022
B3	3	W	3,135	36/1,800	39·6/1,800	116·1/ Constant	1,264
B4	4	W	4,180	48/1,800	52·8/1,800	155/ Constant	1,570
Marine							
AVA1M	1	A	553	6/1,800	—	17·5/ Constant	513–595*
AVA2M	2	A	1,106	12/1,800	—	35/ Constant	661–741*
PH1M	1	A	659	8·2/2,000	—	21·91/1,000 –1,800	517–599*
PH2M	2	A	1,318	16·4/2,000	—	43·82/1,000 –1,800	645–745*
PC2M	2	A	696	10/3,000	—	17·44/ Constant	552–572*
PC3M	3	A	1,044	15/3,000	—	26·15/ Constant	655–675*
PC4M	4	A	1,392	20/3,000	—	34·87/ Constant	719–739*
PD2M	2	A	2,257	24/1,800	—	70·4/1,800	1,126–1,176*
PD3M	3	A	3,387	36/1,800	—	105·6/1,800	1,281–1,331*
PD4M	4	A	4,515	52/1,800	—	151·5/1,800	1,486–1,536*
PDV6M	6	A	6,676	78/1,800	—	236/1,200	1,900–1,960*
PDV8M	8	A	9,033	104/1,800	—	315/1,200	2,344–2,444*
AV1M	1	W	553	6/1,800	—	17·5/ Constant	518–600*
AV2M	2	W	1,106	12/1,800	—	35/ Constant	701–781*
PH1WM	1	W	659	8·2/1,800	—	21·91/1,000 –1,800	518–600*
PH2WM	2	W	1,318	16·4/1,800	—	43·82/1,000 –1,800	701–781*
B2M	2	W	2,090	20/1,500	—	70·4/ Constant	1,179–1,229*
B3M	3	W	3,135	30/1,500	—	105·5/ Constant	1,421–1,471*
B4M	4	W	4,180	40/1,500	—	140·9/ Constant	1,727–1,777*

* Depending on gearbox.

John Robson (Shipley) Ltd.

All these engines are horizontal single- or twin-cylinder models for industrial applications. The RB engine has the water hopper for cooling integral with the engine, and for short periods may be run without an additional water supply. Direct injection of fuel is employed with overhead valves, the cylinder liners being of the wet type. A single flywheel is provided. The RC engine is a larger model of similar design to the RB, and is provided with two flywheels.

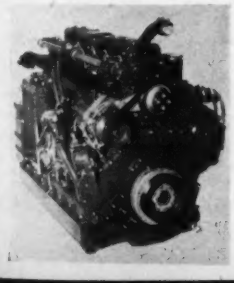
The A type engines are of greater b.h.p. than the RB and RC series, and are available with flywheels suitable for the specific application of the engine.

Basic type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
RB	1	1·67	13/1,100	14/1,100	67/1,100	1,010
RC	1	3·70	22/800	24/800	158/800	2,072
A17	1	7·04	17/430	19/430	232/430	3,052
A21	1	8·82	21/400	23/400	301/400	3,500
A26	1	12·4	26/370	29/370	412/370	4,718
A32	1	15·8	32/340	35/340	540/340	5,782
A40	1	21·82	40/320	44/320	722/320	7,308
A50	1	28·2	50/300	55/300	960/300	10,542
A60	1	36·5	60/280	66/280	1,240/280	12,684
A75	1	47·6	75/260	82/260	1,640/260	15,722
A88	1	60·8	88/240	97/240	2,130/240	17,388
A100	2	56·4	100/300	110/300	1,920/300	17,538
A120	2	73·0	120/280	136/290	2,480/280	21,582
A150	2	95·2	150/260	169/268	3,280/260	23,604

Rolls-Royce Limited

The horizontal Rolls-Royce engines are primarily for rail traction, but are equally well suited to other applications. Modified versions of all the engines can be made available to suit specific applications, such as automotive, industrial and marine purposes, and various forms of power take-off, i.e. fluid drive or torque converters, can be fitted. Handed versions of the engines are possible.

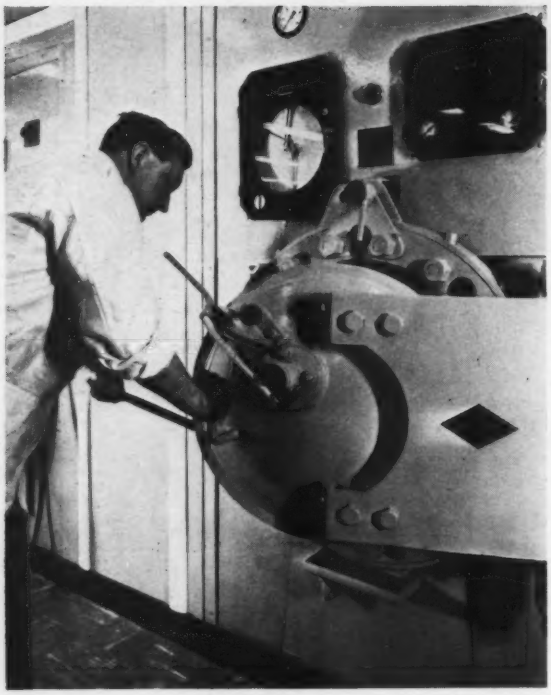
The engines operate on the four-stroke principle, with direct injection of fuel into an open type of combustion chamber. Wet replaceable cylinder liners are used, and the overhead valves are operated from a gear-driven camshaft; the supercharged models employ a Rootes-type blower and are designated S in the table, while turbocharged engines carry a T in the type number.



Six-cylinder automotive.

Basic type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
C4.N	4	8·1	113/1,800	140/2,100	380/1,400	1,990
C4.S	4	8·1	140/1,800	183/2,100	530/1,300	2,200
C6.N	6	12·17	170/1,800	210/2,100	572/1,300	2,500[1]
C6.S	6	12·17	210/1,800	275/2,100	790/1,300	2,790[2]
C6.T	6	12·17	235/1,800	300/2,100	850/1,400	2,690[3]
C8.N	8	16·2	227/1,800	280/2,100	764/1,400	3,100
C8.S	8	16·2	280/1,800	366/2,100	1,044/1,400	3,400
C8T	8	16·2	315/1,800	400/2,100	1,135/1,400	3,370
C6 (horizontal) N	6	12·17	178/1,800	210/2,100	572/1,300	2,460
S	6	12·17	233/1,800	275/2,100	790/1,300	2,580
T	6	12.17	262/1,800	300/2,100	850/1,400	2,500
C8 (horizontal) N	8	16·2	238/1,800	280/2,100	764/1,400	3,220
S	8	16·2	312/1,800	366/2,110	1,044/1,400	3,340
T	8	16·2	349/1,800	400/2,100	1,135/1,400	3,250

* These values are for rail traction
[1] 2,730 with dry sump lubrication.
[2] 2,860 " " " "
[3] 2,730 " " " "



This autoclave, in the Du Pont laboratories at Berkhamsted, is fitted with interlocks to prevent the operator from releasing the door-catch mechanism while it is under pressure.

SAFETY IN MACHINE DESIGN

After emphasising the designers' responsibility with regard to safety, and listing twenty-five dangerous parts, the author discusses the influence of increased mechanisation, and gives some examples of safe and unsafe designs

by **V. A. BROADHURST, B.A., M.W.E.S.**

THE Factories Acts place certain restrictions upon designers of machinery for use in industry. Strictly, the statutory requirements are put on the ones who sell or hire out the machinery (or their agents). In practice, this usually means the designer's employer. The statutory restrictions set out in the Factories Acts themselves are of general application, but those contained in Regulations apply only to the industries concerned.

If a new machine is used in a factory without proper safeguards, the factory occupier is liable to be prosecuted by the Factory Inspector. This is so even if the designer has failed in his duty, but it does not endear him to the purchaser of the machine.

Whatever the legal liabilities in an individual case, safety is best achieved by being built into the design and not superimposed later. This is necessarily the task of the designer. Perhaps altering a dimension of no significance in itself may permanently remove a trapping risk, and so attain the ideal of inherent safety by design. At the other extreme, complex problems may arise, as in the safe design of electronic apparatus for automation.

One of the designer's problems is to know what, in the hurly-burly of shop-floor conditions, is dangerous. Whilst some hazards are obvious, others are not. In the words of a well-known High Court judgment: "In considering whether machinery is dangerous, it must not be assumed that everybody will always be careful. A part of machinery is dangerous if it is a possible cause of injury to anybody acting in a way a human being may be reasonably expected to act in circumtsances which may be reasonably expected to occur."

It has been reiterated in the Courts that the careless workman has to be protected, and that foreseeable acts have to be contemplated when assessing danger.

The Dangerous Parts of Machinery

It is of practical assistance to study the list of the twenty-five dangerous parts of machinery drawn up by H. A. Hepburn, who was formerly Deputy Chief Inspector of Factories. Briefly, these are:

(1) Revolving shafts, spindles, mandrels and bars, e.g., spindles of vertical drilling machines.
(2) Intakes of belts and pulleys, chains and sprockets and the like.
(3) Intakes of pairs of revolving parts, such as toothed gearing and in-running rolls.
(4) Revolving beaters, spiked cylinders and similar parts.
(5) Rotating discontinuous parts, e.g., fan blades and open arm pulleys.
(6) Traps between revolving mixer arms and casings, e.g., trough mixers.
(7) Traps between rotating control handles and fixed parts, e.g., traverse handles of lathes.
(8) Revolving worms or spirals in casings, e.g., worm conveyors.
(9) Revolving high-speed cages in casings, e.g., hydro extractors, centrifuges.
(10) Projections on revolving parts, e.g., set screws.
(11) Revolving drums and cylinders, e.g., foundry rumblers.
(12) Projecting metal fasteners, e.g., on driving belts.
(13) Traps between reciprocating tools and dies, e.g., of power presses.
(14) Reciprocating knives, e.g., guillotines.
(15) Rotating cutting tool edges, e.g., milling machines, circular saws.
(16) Gears and rack strips, e.g., the inter-roller drives of printing machines.
(17) Nips between connecting rods or links and rotating wheels, cranks or discs, e.g., side motions of certain types of printing machines.
(18) Closing nips between platen motions, e.g., letterpress platen printing machines.
(19) Cutting edges of endless band cutting machines, e.g., band saws and band knives.
(20) Pawl and notched wheel devices for intermittent feed motions, e.g., power press dial feed tables.

(21) Revolving wheels or cylinders working in pans or on tables, e.g., edge runners.
(22) Traps between fixed and unidirectional moving parts, e.g., bucket elevators in casings.
(23) Revolving wheels, such as abrasive wheels.
(24) Reciprocating and fixed parts (other than the tool and die type), e.g., sliding tables and fixtures.
(25) Moving balance weights and deadweights, e.g., lift counterbalance weights.

Extensive though this list is, it does not comprise all the dangerous parts of machinery. With some machines, for instance, there is a risk of fragments of the machinery, or of the material it is working on, being thrown off. Two well-known examples are the disintegration of a manufactured abrasive wheel, and the violent ejection of wood being cut with a circular saw. There are dangers arising in connection with parts of machinery under steam pressure, such as cylinders. Each designer needs to assess the hazards for the kind of plant in which he specialises.

Ergonomics and Work Study

Long-term trends in industry have a great effect on the safety aspects of machine design. A greater interest in and knowledge of industrial safety has been a characteristic of recent years, among management and men, their associations and unions, and the Government, as well as designers.

During the Second World War an impetus was given to ergonomics. Among other matters, this involves a shift of emphasis as design is built up round the human operator. It is the machine which has to be adapted to the man, not the man to the machine. Machine controls become an extension of the operator's fingers, the vital link between man and machine. The dimensions, shape and the location of parts of the machine, and the whole concept of machine operation, are considered from the operator's standpoint.

Allied with ergonomics, with its emphasis on the human factor in design, is the modern work study movement. Skilled method study reveals defects in the design of machinery under operational conditions. Some faults have a safety aspect, as when fatigue is produced by different movements needed to operate a machine. Power-assisted devices for reducing the effort of operators, of garment presses, for example, reduce fatigue, which is often an element in accidents.

In one case a heavy machine was used for making pre-cast concrete beams, and had to be moved daily as the work proceeded. It had no wheels, so a team of men, at the cost of quite a lot of time and effort, had to struggle to move it each time. No provision had been made for the four-core, 400-volt cable to be detached from the motor, and the cable was damaged during a move. This led to one of the men receiving a serious electric shock.

No one had appreciated the unsafe features in the design beforehand, but after the accident alterations were made to improve the safety of the machine. These included means of moving the machine easily, and of disconnecting the cable at the motor; also the voltage was reduced. All these steps could have been taken at the design stage if the day-to-day operation of the machine had been seriously studied.

Another example concerned the design of a safety catch on a foundry ladle. The designer had provided two lugs for the safety catch so that, for pouring molten metal, one could be raised whilst the other acted as a back stop. As should have been foreseen, both lugs were accidentally left up one day, and the ladle of molten metal tilted the wrong way, so that a workman was so severely burned that he died. A safer design is the geared ladle.

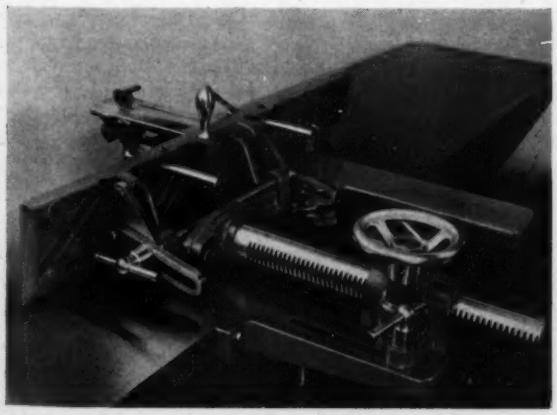
Individual Machine Drives

The dangers inherent in overhead shafting, both in cleaning and repair, have lessened, largely as a result of the progressive introduction of individual electric motor drives—although there are still many factories with a lot of overhead shafting. Now that individual motors are often incorporated within the framework of the machine, the designer should plan for them if safety is to be ensured.

In the case of one small food-processing machine which incorporated its own electric motor, the drive was by multiple V-belts and pulleys—efficient but dangerous. To guard this drive, the designer panelled in the lower part of the machine, giving the machine a clean appearance suitable for the food industry. Unfortunately, although the machine was sold complete with motor and controls, the designer overlooked the fact that the motor controls were placed inside the panelling, some of which had to be removed to operate the machine.

Another development which has influenced safety is increased machinery speeds. The safety implications vary with different machines. Hand-fed machines, when speeded up, give less time to the operator to feed and take off, and may give rise to fatigue (with its effect on safety). Where automatic guards are provided, these also need to be speeded up. The timing of automatic guard operation becomes critical, and even a slight malfunctioning within the narrower permissible time margins may lead to danger.

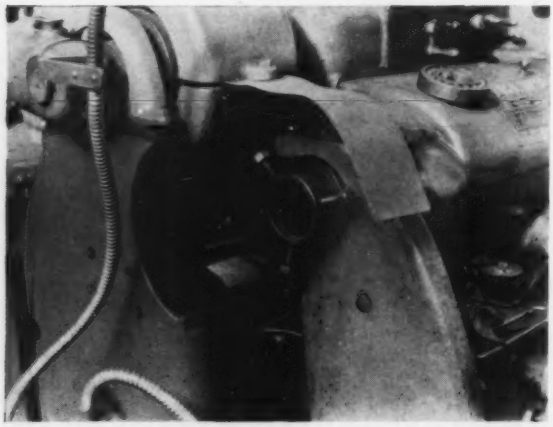
Where the machines are speeded up by the user, hazards may arise for which the designer cannot be blamed. Thus, shortening the stroke of some machines may destroy the necessary safety margin allowed in guard design.



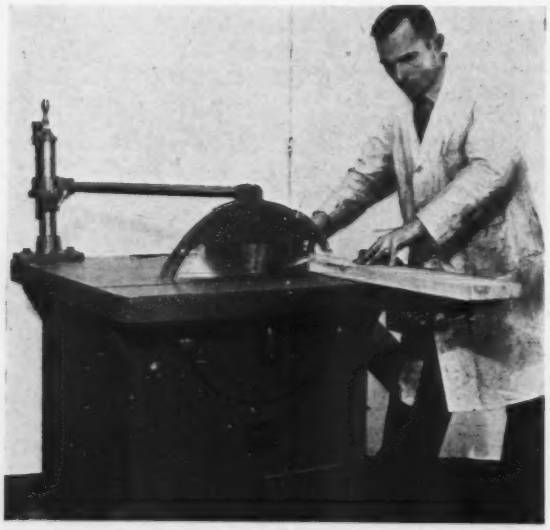
The cutter guard (shown behind the handwheel) on the Wadkin wood planer allows only the operating part of the cutter to be exposed.

Besco-Truecut guillotine (by F. J. Edwards Ltd.), in which external guards are not necessary because the operating mechanism is totally enclosed.

The handwheel of this foundry ladle makes use of natural movement in that turning it to the left causes the ladle to tilt in that direction, and vice versa.



Projecting set bolts and screws, and similar parts, are dangerous and should be properly enclosed, so that makeshift guards like the one shown do not have to be fitted by the user.



Safety features on this Wadkin saw include a prominent mushroom-headed stop-button, and controls well placed for the operator.

Not only the machinery but the associated fencing is liable to heavier wear and tear when machines are made to run faster. This is another reason for the guarding to be designed by the designer and not added later. Faster machines produce more waste, and as many accidents occur during the removal of swarf and waste generally, the implications for safety should be contemplated at the design stage.

Increased Mechanisation

Another and familiar long-term trend which affects safety is increased mechanisation. Many former hand operations are now done by machine, and, more significantly, some work is done by machine which otherwise could not be done at all. The best illustrations come from the nuclear industry, where some work is done by remote control which otherwise, for health and safety reasons, could not be done at all.

But mechanisation of a process does not necessarily increase safety, although it has brought great gains in safety. The use of mechanical feeding devices (particularly on inherently dangerous machinery like circular saws) and mechanical handling have prevented many machine accidents, weight-lifting strains and other injuries whilst handling goods.

A basic improvement, made for production reasons, in the design of a printing machine also increased safety. The increasing use of higher-speed printing machinery focused attention on the increasing proportion of time during which the machine was not printing, i.e., during the preliminary stage of "make ready". To improve the productive period of the machine, therefore, the designers arranged for the cylinders to be easily removable, and provided a duplicate set. Consequently, "make ready" was done away from the machine, which meanwhile was printing with the other set of cylinders. The gain to production was obvious, but it has an important safety aspect, because a lot of accidents arise during the "make ready" at a printing machine.

The more advanced form of mechanisation, automation, increases safety in some respects. Fewer men are employed, with hence less risk of accidents, and automatic handling of components obviates manhandling, with its large crop of accidents. But there is another aspect of the matter. Maintenance work at automated equipment is liable to be urgent and done under pressure, which usually means less time and care for safety. In assessing the safety of automatic plant, hazards which might affect the maintenance man or electrician, who might be needed anywhere, are easily overlooked.

In one automatic foundry, an operation was temporarily proceeding by hand cycle whilst a breakdown of a section of the plant was being dealt with. A man was manually operating a moulding machine whilst the power was off for the repair, but was injured on the sudden resumption of automatic operation, of which he received no warning.

Electrical and electronic systems play a large part in automation, and the need to repair breakdowns hastily offers a prospect which is not too safe. Special safety precautions need to be planned and carried out by men who are both skilled and disciplined. The design of control systems and instrumentation presents safety problems. The design of foolproof systems may be needed, as in the case of a rotary variable speed machine so as to make it inherently incapable of overspeeding.

Designing for Safety

It is a fundamental safety principle that machinery should be designed to be intrinsically safe wherever possible. This is achieved relatively simply in some cases, as when the gap between a moving part and a fixture is increased so that the distance is always too great to form a trap.

Where safety cannot be built into the design in such ways,

safeguards have to be added to avert danger. These often take the form of physical guarding. Both law and principle require a fixed guard where practicable. Interlocked or automatic guards are also used in suitable cases.

Photo-electric devices may be used provided that they have certain features, such as those embodied in the standard drawn up by the Joint Standing Committee on Safety in the Use of Power Presses. Photo-electric devices need to be self-checking and designed to fail to safety; also, the response-time of the device and the stopping-time of the machine must be rapid enough to prevent injury to an operator reaching through the protecting ray to the danger area.

The nature of the materials used in machine construction may affect safety in less obvious ways. Once, before the dangers of bursting from overspeeding of inner cages of hydro-extractors were appreciated, cast-iron outer casings were sometimes used. With modern experience of such machines, this danger is now fairly obvious.

But the help of designers is sometimes sought by machine users, struggling with a safety problem. In the bakery industry, where accidents happen during the dangerous but convenient practice of cleaning dough adhering to moving machinery, the designers' assistance was requested. At one machine, a special material was consequently used in covering the rollers of one machine, so that the dough would not adhere to them.

Ergonomics research has produced some illuminating data on control devices for machinery, with regard to their type, shape, dimensions, direction of movement and location. Controls should be designed for functional purposes, and this usually means making them look different, not alike. In one sheet-metal works a man lost the ends of two fingers when his mate pressed the wrong control button. The designer, rather than the operator, was at fault, because the nine control buttons for this machine were in line, like a row of identical peas.

A very common case in which safety is enhanced by the distinctive shape of control buttons is the familiar motor stop-start buttons. In emergency the stop button may be needed urgently, and making it a projecting mushroom-headed control has proved of great safety value in many cases. To make the buttons alike except for the colours, which with time become increasingly alike, is a poor substitute.

The design of the clutches of power presses has received a lot of attention by an official committee. Clutch design and the possibility of uncovenanted repeat strokes are important subjects in machine design generally.

Dangerous parts such as those enumerated in the list given above may be planned away, rather than provided with guards. Thus, instead of guarding a trap between a moving part and a fixture, dimensions may be altered so as to eliminate the trap. In a paper mill, a man's head was caught between two rolls when he slipped. These rolls, which were not in-running and did not require to be near one another, could have been placed relatively to one another so that no trap existed.

Official Interest

Official committees, including international ones, have long been interested in safety in machine design. Those people concerned with hydro-extractor and centrifuge design should be familiar with the Recommendations of the Sub-committee on Industrial Health and Safety (of the Brussels Treaty Permanent Commission), first published in 1953.

Official interest in safety in machine design is considerable, and of increasing scope. The Chief Inspector of Factories has said: "Bearing in mind the large numbers of firms and their staffs who are concerned with the design of machinery whose capabilities for inflicting injury are considerable, it must be said that there is a great deal of ignorance as to techniques of safety and safe design." Perhaps, as the nuclear age develops, he will have cause to change his opinion.

FOR FURTHER READING:

"The Designer and Radiation Protection", by H. J. Dunster. *Nuclear Engineering*, **1**, No. 4, p. 144, July 1956.
I.C.I. Engineering Code B.1.1. "Safe Layout, Design and Installation of Machines", R.S.P.A.
"Machine Controls", by V. A. Broadhurst. *Machine Shop Magazine*, **18**, No. 9, p. 541, September 1957.
"Safety in Design", by B. Shackle. *Proceedings* of the *Engineering Materials and Design* Conference, February 1960.
Electrical Safety, by H. W. Swann (Macdonald).

INDUSTRIAL RADIOGRAPHY

THE non-destructive testing of materials and components by radiography is increasing, because of the need for perfection in the construction of modern equipment. The ability to inspect the internal state of almost any product without affecting the material from which it is made is of great value at almost every stage of manufacture, as well as with the finished form. It is cheaper to discover porosities, slag inclusions or other flaws in a raw casting than it is to discover these defects only after money and time have been expended on machining. Radiography can not only be used for inspection of fabrication, for instance welding, but can be used on the final product to see whether concealed assemblies are properly positioned.

In order to cover the wide range of objects which may need to be tested, several x-ray units and isotopes are needed, for no single unit or isotope is suitable for all jobs. Radio-isotopes have certain advantages over machines in that they are considerably cheaper than x-ray equipment of comparable energy. Also, the gamma ray source is very small and can be used in cramped areas. Furthermore, the radiation is emitted in all directions, so it is easy to radiograph an entire circular weld in one operation. In addition isotopes need no electrical supply.

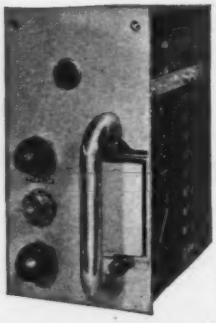
X-ray machines have the advantage of being adjustable as to the energy of their penetrating rays, so they can be regulated within limits to suit the thickness of material being examined; also, since they have no radio-activity, the machines can be turned off, and need not incorporate shielded storage space.

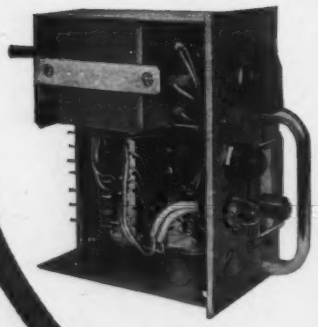
The following table gives x-ray energies appropriate to some typical materials:

kV.	*Aluminium* (*in.*)	*Steel* (*in.*)	*Bronze* (*in.*)
50	½-1	—	—
140	1-3	½-2	½-1
200	3-5	1-3	½-1½
260	—	2-3½	1-2
300	—	2-5	2-4
1,000	—	3-6	3-5
2,000	—	4-8	—
24,000	—	6-20	—

Gamma rays given off by radio-isotopes are physically and radiographically equivalent to x-rays, so it is possible to rank various isotopes by comparing them to their approximate equivalent x-ray energies, as follows:

Isotope	*Half-life*	*Equivalent Energy* (*kV.*)
Cobalt 60	5·3 years	2,000
Iridium 192	75 days	400
Cæsium 137	30 years	600
Thulium 170	27 days	100
Samarium 153	47 hours	75





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For its price, EMIAC II is easily the most versatile analogue computer available today. It enables the smallest user to order a "one off" computer at a mass produced price, whilst the largest organisation can obtain a general purpose computer or a special simulator of any desired size and characteristics. In every case the user buys only what he needs and receives no redundant equipment. How is this done?

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In EMIAC II the same small range of standard amplifiers will add, integrate, multiply, divide, reverse polarity or generate a function. All needed changes are made by the 'C' Box which makes the appropriate connections to the Patch Panel, arranges the corresponding switching and contains the components required for the particular computation. A range of eight 'C' Boxes covers the most frequently used functions. They are readily interchangeable and plug conveniently into the front of the computer. Reserve 'C' Boxes can, of course, be held to extend the computer's versatility. Their small size presents no storage problems.

The right computer for you

We invite you to let us know your special requirements for an analogue computer. We then suggest the ideal equipment for the purpose, together with any reserve components for secondary applications. Finally we assemble the equipment ready for use. We will be glad to demonstrate the computer and discuss your particular problems.
Full literature on EMIAC II is available.

On the left, an engineer removes a 'C' Box, two typical examples of which are shown.

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EE 34

NEW IDEAS IN DESIGN

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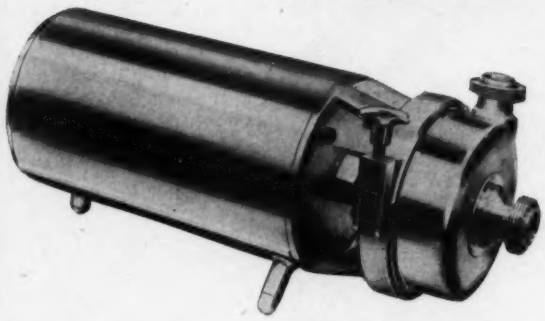
Pump Designed for Easy Cleaning and Servicing

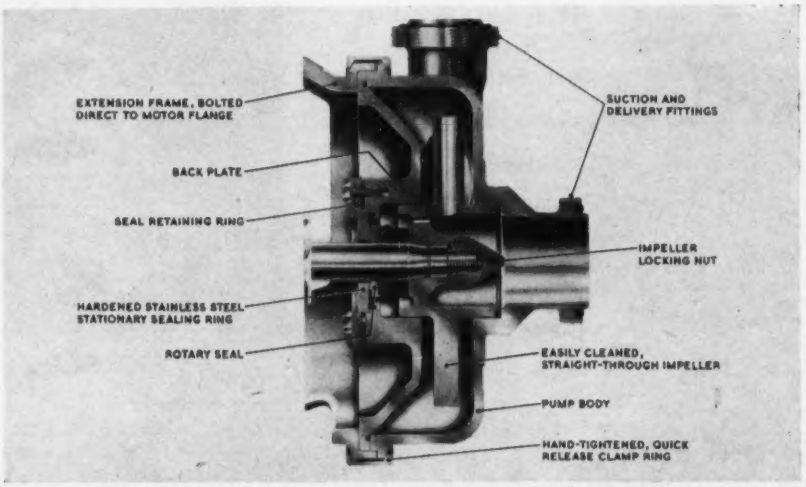


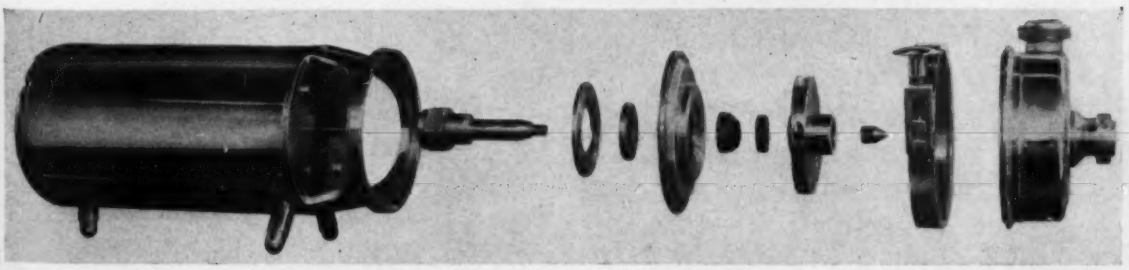
THE Puma range of pumps, exhibited at the recent Brewing and Allied Trades Exhibition at Olympia, is intended for the brewery, dairy, food and other portable liquid industries, where it is essential that servicing and cleaning be carried out simply and easily. The manner in which this has been achieved (by the A.P.V. Co. Ltd.) is noteworthy, and it is surprising that some of the ideas embodied in the Puma range have not been used before.

The exploded and sectional views of the pump show that its main components can be dismantled by first removing the hand-tightened stainless-steel sealing ring, and then, when the impeller locking nut has been removed, sliding away the pump body, the impeller, the seal components and finally the backplate. An unusual feature is the stub shaft, which does not employ the normal keyway but is provided instead with a split tapered collet which ensures concentric running. This collet can be provided with different bores to fit various motor shafts. Being a separate component, it can easily be replaced.

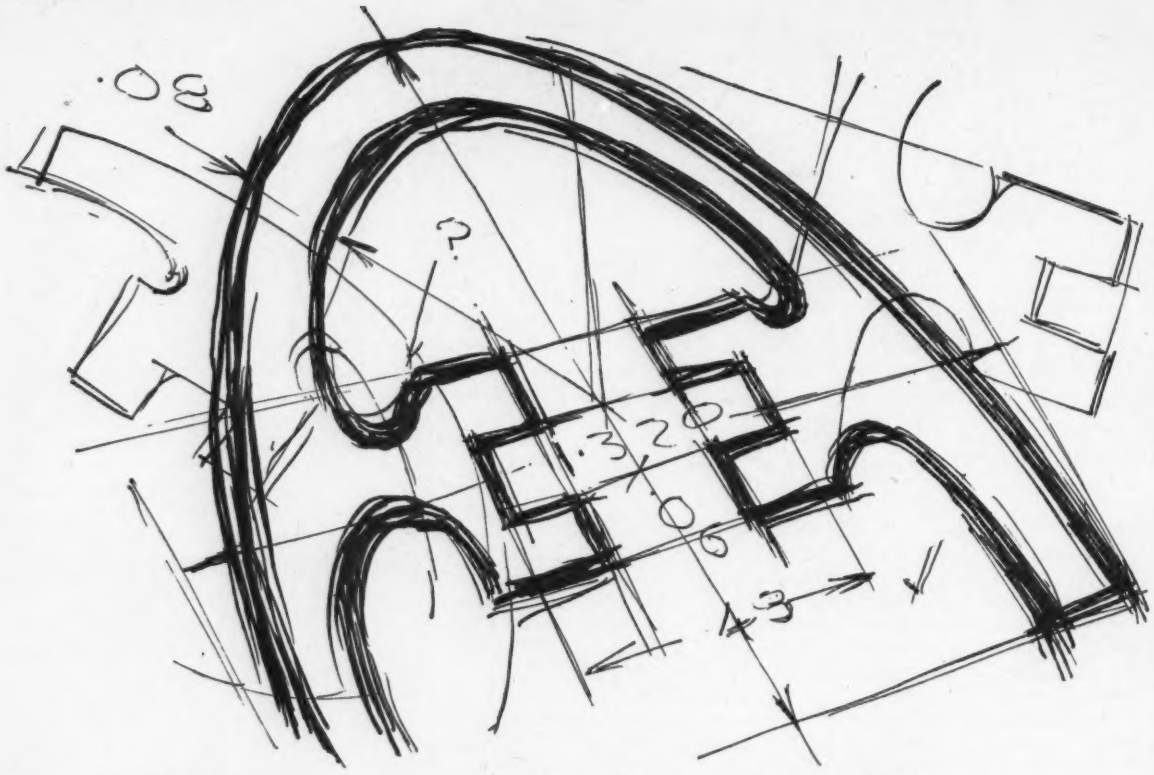
The impeller is a machined component, the fluid flow being through straight bores and not by conventional blading. The seal, which is of the carbon face type, is normally a Crane No. 6, but other seals may be fitted, provided that they are made for a 1 in. diameter shaft and are not over 1 in. in working length. The seal is in no way dependent upon the lubricating properties of the liquid being pumped. The carbon face of the seal bears against a hardened stainless-steel sealing ring. This component is lapped on each side, which ensures that it has double the effective service life. All pumps in the Puma range may be equipped for water cooling of the seal area, as may be necessary when hot or sticky liquids are being pumped. Industrial versions of these pumps are available for liquids other than food products, and these can be supplied with packed glands.

The Puma pump is constructed throughout in 18/8/3 stainless steel. The range is based on three standard pump sizes, 1½, 2 and 2½ in., with alternative sized suction connections to cover duties extending from zero flow at a maximum pressure of 114 p.s.i. to 16,000 gall./hr. at 20 p.s.i. All pumps employing motors up to 5 h.p. are fully shrouded as standard. Above 5 h.p., pumps are supplied unshrouded only. Shrouded pumps have a combined ball-footed cradle and extension frame which will accept the flange spigot of a wide range of standard BSS, NEMA or CEMA motors. The unshrouded pump has an extension frame with no cradle, using foot-mounted motors to the same standards.





EMD 4206 for further information



the designer and the doodle

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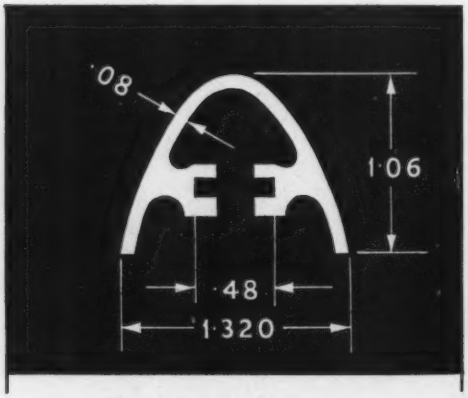
Our advice on designs is given without obligation, and the best time to bring us in is right at the beginning.

So even if you have an idea that is no more than a doodle, why not doodle it in the space next to our example and get us to comment on it?

Designers are invited to send for a copy of our standard sections catalogue.



Sketch dimensioned section here

BM267

Birmetals

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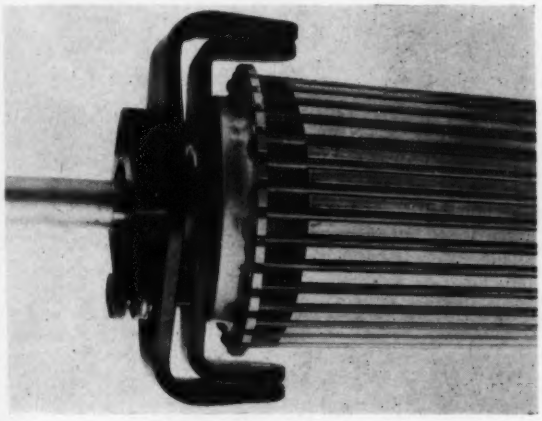
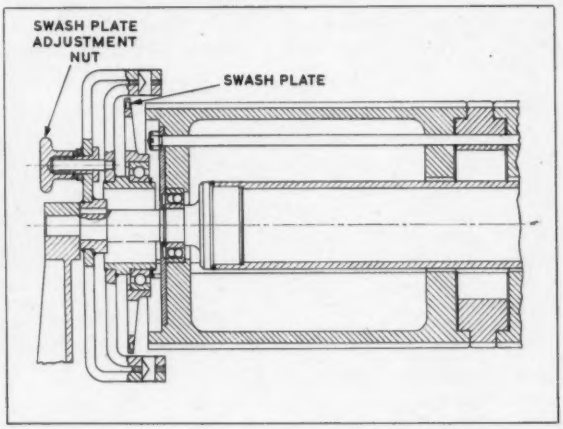
Web Spreading Roller Uses Elastic Bands

IN the production of paper and thin plastics films, it is essential that there be no creases in the product as it is wound into reels.

An ingenious web spreading roller, introduced by Vacuum Research (Cambridge) Ltd., has been developed to counteract this tendency. It was designed originally as part of a high vacuum metallising process, but is now offered separately for application in other situations where the same problem is encountered. The surface of the roller is inset with elastic cords which are fixed to a swash plate at each end. The sectional view of the end of the roller shows that the angle of inclination of the axes of the swash plates to the axis of the roller can be altered by means of knurled screws which pivot the swash plates on gimbals. The inclination of the swash plates causes the elastic cords to be stretched and relaxed once during each revolution of the roller. The web is arranged to be in contact with the cords in the position in which they are being extended. The rollers may be free running or driven. Although it is not normally necessary, the two swash plates may be coupled through hydraulic actuators.

The roller is claimed to perform the de-creasing operation without introducing a bow into the web, and the amount of spread is easily adjustable.





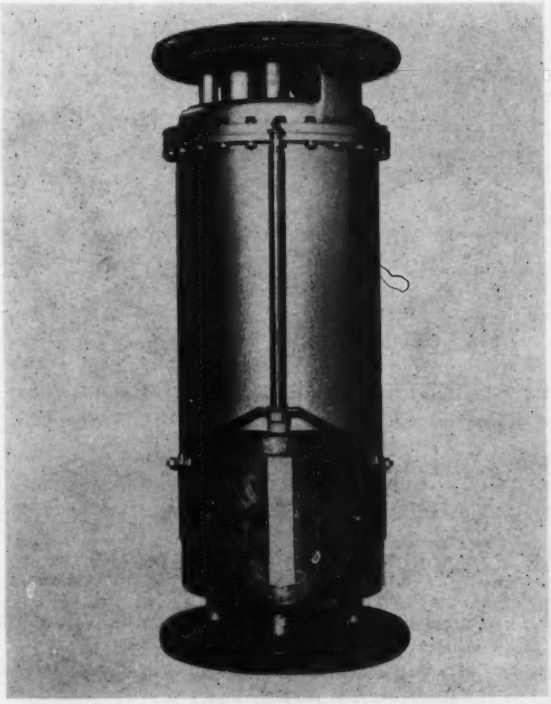
New Lightweight X-ray Unit

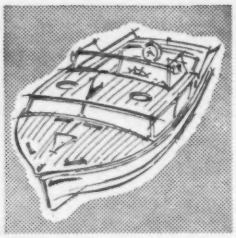
FOR the examination of welds in tubular vessels down to 3 ft. in dia., a new portable x-ray unit of 150 kV. capacity has been introduced by Pantak Ltd.

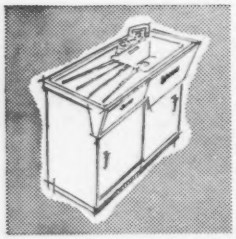
The new unit, known as the Baltospot G150, is available in two models, the type D head having a 60-deg. field, and the type P a 360-deg. field. In both units the beam angle is 35 deg. and the head is offset. The focal spot size of the tungsten target is 1·5 × 1·5 mm. in the E150D, while that for the G150P is 0·8 × 2·1 mm. A particular feature of the offset head is its use, especially in the panoramic version, when examining closed vessels of small diameter, even when these are fitted with welded dished ends.

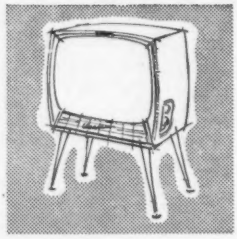
Sulphur hexafluoride is used for both insulation and cooling of the x-ray tube, forced circulation cooling of the anode being effected by means of an internal blower. The tankhead is of drawn aluminium with bolted dished ends, and the numerous protection devices fitted include shock-absorbent mountings for the tube in the tankhead, and further shock-absorbent mountings for the tankhead in the cradle. A thermoswitch is fitted to guard against excessive temperature rises. The length of the tankhead is 1 ft. 9 in., and the diameter 8¼ in., the weight being 46 lb. The weight complete with end rings is 51½ lb., and the weight of the protective cradle is 6½ lb.

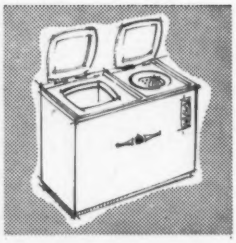
The control unit operates from a 220-volt 50-60 cycle a.c. supply, using 6 amp., and accommodates main fluctuations of 10 per cent either way. Stepless-type kilovoltage and tube current controls are incorporated, giving continuously variable control. Exposure charts for 16 in. and 28 in. focus-to-object distance are supplied in the lid. The control case is 1 ft. × 9⅞ in. × 6½ in., and the weight 27 lb.

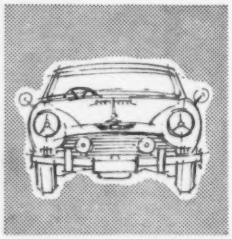


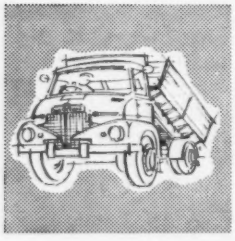




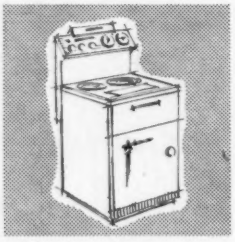


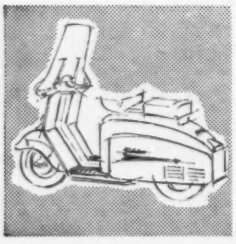


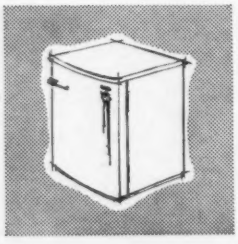




DECORATIVE TRIMS







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OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Solidified Liquid Gas

A method of producing solidified liquid gas has been developed at the Institute of Mineral Fuels of the Academy of Sciences, U.S.S.R., the work being carried out at the Laboratory of Chemical Treatment of Solid Fuel under the direction of its head, Prof. B. Losev. To produce this fuel, liquid butane is mixed with urea-formaldehyde resin, polyvinyl alcohol, casein and glycerin to form cell partitions or walls resembling a honeycomb. Under the action of formalin, the film forming the cell walls solidifies, thus sealing in the liquid gas. In this manner a briquette is produced which has the appearance and properties of a solid, 5 per cent of the briquette consisting of the solid film, the rest being liquefied fuel.

Solidified liquid gas is a cream-coloured porous mass resembling cheese in both appearance and consistency, and may be cut with a knife. When ignited with a match, it burns steadily, slowly and evenly. The briquettes have a high heat content, only 4-5 gm. of the gas being required to bring a litre of water to boiling point. The solidified gas has a lower specific gravity than any other fuel and can be conveniently transported and stored, the solidified gaseous fuel remaining unchanged under any climatic conditions, and burning in any weather. The briquettes can be easily converted into liquid fuel by means of a press, and the fuel so recovered is superior in its properties to an unconverted liquid fuel of the same type.

The new fuel has been tested and found satisfactory by members of a scientific expedition to the Antarctic. It is not yet being produced on an industrial scale, and can be obtained only in small quantities from the Institute of Mineral Fuels of the Academy of Sciences, U.S.S.R.

Synthetic Paper

Synthetic fibres have recently been developed to produce a new paper fabric suitable for making printing, writing and structural materials, and protective coverings. Known as Papertex, the new product is the result of a combination of synthetic resins and fibres. Although several different types of Papertex are produced, the basic process is the same for all, and consists of choosing a resin possessing certain mechanical properties, selecting a certain type of fabric to be used as a support, and using quantitative criteria for the association of the two. The process has been developed by SPERI (Società Produzione e Ricerche Industriale), of Milan.

The paper is produced in several weights and finishes suitable for offset printing and silkscreen and letterpress printing. A special treatment is also available to make it suitable for sensitisation for photographic purposes.

As a material for printing and writing, it is characterised by great resistance to breaking and tearing, since it is not sensitive to dampness, and resists abrasion. In some cases its mechanical properties are actually improved by dampness. It has a resistance to water which is immensely superior to that of ordinary paper, and is moistened only with difficulty, and in a non-uniform manner.

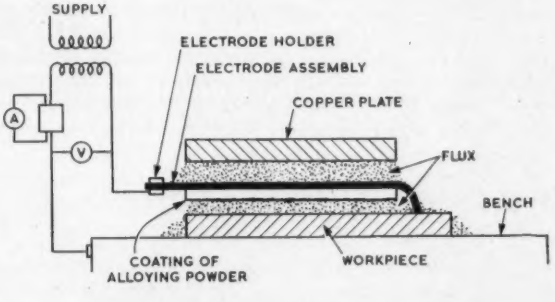
Cutting can be effected in the usual manner, although it is advisable to use very sharp blades to prevent the edges becoming frayed. There is no difference in the dimensional stability of the new fabric as compared to the usual types of paper, and it exhibits the usual machine and transverse directions. It can be worked under heat at temperatures varying from 80-100 deg. C., and it is possible to join two sheets by fusion; no curling occurs. Although Papertex is treated with anti-static products, the effect does not last indefinitely.

Horizontal Plate Electrode

A new rapid process of semi-automatic hard-facing with a horizontal plate electrode has been developed and put into operation in the U.S.S.R. The surface of the workpiece remains horizontal during the hard-facing operation, the electrodes consisting of metal plates of suitable size and shape. The metal deposited consists of a powder mixture, the composition of which depends on the properties of the workpiece. Hard-facing can be carried out either immediately, with the powder mixture dry, or after it has been applied to the metal plates as a coating.

Welding with a horizontal electrode is a simple operation. It does not require complicated apparatus or a great deal of skill on the part of the operatives; it is rapid and gives welds of high quality. It is especially effective for welding in places that are inconvenient or difficult to reach, and for welding thin sheets.

The electrode is covered with a layer of flux 10-15 mm. deep, on top of which is laid a copper plate. To make it easier to strike the arc, one end of the electrode is bent, so that during assembly it presses against the workpiece. Hard-facing is carried out automatically, the arc moving continuously over the fused edge of the plate electrode, melting it uniformly and forming a pool of molten metal about the same shape and size as the electrode.



Research and industrial experience in using the new method have shown that, when hard-facing with a plate electrode, output is raised several times compared with existing manual hard-facing methods. Metal deposited by a plate electrode is dense, and free from pores, blowholes and slag inclusions. It has a smooth surface resembling that of a casting, thus prolonging the service life of parts operating under abrasive wear conditions. It contains very few cracks, if any. By varying the gap between the electrode and the workpiece, the penetration can be minimised; this increases the degree of alloying of the hard-faced metal.

Plastic Associates' new adhesive for rubber to metal bonding, PA-820, is shown here being applied by brushing.

New Adhesives

Two new adhesive systems, one for bonding rubber to metal and the other for chemically uniting nylon to metal, are now available from Plastic Associates, California, U.S.A.

Based on a polyurethane formulation, the new adhesive for rubber to metal bonding (PA-820) cures at room temperature to form a tough, flexible bond. Since no heat or pressure is required, the adhesive is ideal for such applications as attaching rubber feet to metal instrument cases, or installing flexible seals on cabinet doors. The parts to be joined are coated with adhesive, air-dried for a few minutes, then pressed firmly together, the immediate grip of the adhesive being sufficient under normal conditions to allow further assembly without any delay. The adhesive continues to cure for several days, achieving an ultimate tensile strength that may in certain cases exceed that of the rubber itself.

The two-step process for chemically "welding" nylon to metal is expected to find widespread use in such applications as the bonding of nylon gears to metal shafts or securing threaded screws or rods in nylon-and-metal assemblies. This new method makes use of an epoxy paste that chemically unites with the metal surface on which it is applied. A separate solvent solution applied to the nylon part softens the surface and allows the nylon to blend with the epoxy bonding agent as the latter hardens. The entire operation is performed at room temperature, and results in an extremely tough, shock-resistance union between the nylon and the metal, within a few hours. The two materials used in the system are supplied in separate containers, the nylon single-compound treating agent being designated as PA-749, and the two-component bonding agent as PA-708.

Non-corrosive Insulation of Aluminium

A new thermal insulating material with a base of rock wool called Sillan may be used in place of glass fibre for certain applications. With the increasing use of light alloy panelling in the building industry, the Instituto Sperimentale dei Metalli Leggeri, in Italy, has carried out experiments to determine the reaction of the new insulating material when in contact with aluminium and its alloys. These results have been compared to those obtained with glass fibre and lava-wool.

Sillan is chemically inert, contains no sulphur or alkali, is non-corrosive, and does not react to hot water or steam (even if these are of an alkaline nature). It is exceptionally light, easily applied, economic, has a high yield, and has highly effective insulating properties. It can be supplied in five forms, as follows: strip, felt, slab, tubing and metal reinforced.

The strip, which consists of rock wool held together by felting, is very soft and has a specific weight of 60 kg./m.^{3}. It is said to be capable of withstanding temperatures up to 700 deg. C.

Sillan felts consist of rock-wool treated with a synthetic resin, and are available in three grades: soft, reinforced and rolled. All three types can be used at temperatures up to 250 deg. C., and are suitable for refrigerators and generators, and the building industry in general.

The slabs are similar to the felts and consist of rock wool treated with a synthetic resin. They are non-flexible, have a specific weight of between 80 and 100 kg./m.^{3}, and withstand temperatures up to 250 deg. C. They are used in the building industry for lightweight covers, ventilation ducts and ceilings.

The Sillan tubing is for thermal insulation of steam pipelines, hot and cold water pipes, and pipes carrying brine for refrigerators. It may be obtained in 500-mm. lengths, with internal diameters from 17-108 mm., and thicknesses of 30-60 mm. Its specific weight is 130 kg./m.^{3}, and it can be used at temperatures up to 250 deg. C.

The reinforced Sillan consists of rock wool mixed with wire netting and other materials such as cotton, asbestos and aluminium. It may be used at temperatures up to 700 deg. C. for repairing pipelines.

The Sillan samples tested by I.S.M.L. for pH value gave 7·3, as compared with 8·9 for lava-wool and 9·7 for glass fibre. Sillan gave a neutral reaction, while the other two gave distinctly alkaline reactions. After a three-month corrosion test at 47 deg. C. and 100 per cent humidity, Sillan, whether in the form of felt or panelling, was found to be inert while in contact with aluminium and its compounds. Other inorganic insulations, particularly those with a magnesium base insulator, gave definite alkaline reactions and were aggressive when in contact with aluminium and its alloys.

Prevention of Corrosion

The corrosion of iron or steel parts and tools during storage or transportation is a frequent occurrence. The most common preventive measures are painting, greasing, packaging in adequate materials, and the application of vapour-base inhibitors.

More recently, attention has turned in an ever-increasing degree towards materials that evaporate at normal temperatures and protect the metal by forming a condensed monomolecular layer on its surface. Correx 2 (a Hungarian product) belongs to the above-mentioned group. It is a volatile solid which is adsorbed on the surface of metals. After being dissolved in the humidity at the surface it exerts a passivating effect at the anodic points, thus preventing corrosion of the metal. Hence it is not hygroscopic, which is an advantage over other inhibitors.

Its solubility in water, however, may be a disadvantage; water in amounts greater than that associated with humidity can wash the inhibitor from the surface of the metal.

Correx 2 may be applied in several ways. Its most widespread use is in application to the surface of wrapping-paper, by embedding it into an adhesive layer. Another application is in packing it into small sacks of some thin material which does not impede evaporation (for instance, muslin), and hanging these sacks in the container.

In certain cases Correx 2 can be dissolved in a suitable solvent and then sprayed on to the surface of the metal to be protected. Owing to its volatility, it protects against corrosion not only in immediate contact with the metal, but also at a certain distance from it. A considerable advantage is the fact that the protected parts or components may be put quickly in working order, whereas the cleaning of goods protected by grease or oil involves a considerable amount of time and expense.

Siemens-Ediswan 60-amp Input Junction Box moulded in D M C in four parts by AEI. (Aldridge) Ltd.

DURABILITY for DMC

Good-looking grille on Morphy-Richards Fan Heater is a moulding by Crystalate (Mouldings) Ltd. in a special "thin flash" grade (L.1834) of Beetle D M C.

Wolf "Safetymaster" Power Tool. D M C mouldings by Minerva Mouldings Ltd. are ingeniously designed to provide double insulation.

Beetle Polyester D M C is equally outstanding for its electrical insulating and anti-track properties as for its high heat resistance and mechanical strength. That's why it is unbeatable for high-duty applications, of which the examples shown are typical. D M C is economical because it is fast-curing and simple to mould under low pressure in conventional compression and transfer presses. Compatibility with metals and dimensional stability are above normal for thermosetting materials.

Two glass-filled types are available: Type A for general purpose and electrical components; Type B, a self-extinguishing material. Also Type C, an economical sisal filled compound. Write for full details.

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New Books

Elementary Engineering Mechanics. *By Eugene G. Key.* (*John Wiley; Chapman & Hall—44s.*)

Of the numerous textbooks published on the subject of mechanics suitable for engineering students in their early years of study, this latest contribution will be of very great value. Mathematical knowledge beyond simple geometry and algebra is not required. Knowledge of the basic principles of trigonometry will be useful, although all problems introducing trigonometrical solutions are fully explained during the text.

The book is divided into two parts. Part 1 deals with statics, giving the basic explanations and concepts of this subject. Force systems, moments and couples are fully illustrated and the determination of direction magnitude and result are given both mathematically and graphically. The principles of vector quantity, non-concurrent and non-coplanar forces are explained, and the basic design of simple structures, such as trusses, is illustrated. A portion of Part 1 is also devoted to friction, including its effects under both static and kinetic conditions.

Part 2 is devoted to the theory of dynamics, and explains motions, such as angular, harmonic and rectilinear, and the forces which produce and maintain them. Potential, kinetic and heat energy, and work done by variable forces, are also dealt with in this section.

This volume can be used ideally as a working text, since is has many examples set for individual chapters. Answers are provided for alternate questions. It is well illustrated, and all the solutions given are easy to follow. Tables and other useful information are included, to give a compact and worth-while introduction to engineering mechanics.

Glass—Its Industrial Applications. *By C. Phillips.* (*Reinhold; Chapman & Hall—56s.*)

Within the last few years, glass has become an important engineering material. Details of widely differing applications of this material are contained in this book, which also describes in a clear and practical manner the methods of manufacturing various types of glass product. An important chapter deals with design and dimensional tolerances; this section, allied to chapters on the nature and composition of glass and its physical and mechanical properties, will enable the designer who previously had little experience with glass to be creditably informed.

Other chapters deal specificially with containers, laboratory glassware, and glass in the building and chemical industries. Individual chapters are devoted to glass for electronic tubes and electric lamps, illumination and optical applications. The final chapters deal with fibrous glass and special glasses for specific applications.

The book is well presented, and contains many excellent photographs and practical line drawings.

Applied Mechanics for Engineers. *By James C. Grassie.* (*Longmans, Green & Co. Ltd.—45s.*)

There are few books published that deal with the vast subject of mechanics in such a concise way as this one. The three branches of mechanics—statics, dynamics and strength of materials—covered in this volume are intended to aid first- and second-year Degree students in engineering, and those studying for a Higher National Certificate. The book, although divided into three parts, has, where necessary, appropriate cross-references to other parts, in order to illustrate the interconnection within this field of engineering.

The early chapters are devoted to statics, and give explanations of, and solutions to, concurrent, non-concurrent and coplanar forces. The action of forces on rigid bodies in a state of equilibrium is shown, and the results of forces in three dimensions are explained. Further chapters deal with dynamics, the theory of motion (including rectilinear, uni-axial and curvilinear motion), and rotations about a variable axis. The various forms of momentum, work, power and energy are also explained. Power transmissions, vibrations and balancing of rotating masses, also have chapters devoted to them. The latter part of the book is concerned with strength of materials. The elastic stresses due to the elements of force action, both separately and in any combination, are determined, and subsequently the elastic deformation due to such stresses.

The book concludes with an appendix covering: geometrical properties of sections, vector quantities, graphical differentiation and integration, and also Castigliano's theorems and reciprocal displacements. Many easy-to-follow examples are quoted, and useful exercises are set. Step by step, the principles involved are set out, and it is thus possible to see a solution to any obscure problem. The volume tends to aid engineers by showing methods of approach to some of the more difficult problems.

F. Smith

Machine Drawing and Design. *By W. Abbott.* (*Blackie & Son Ltd.—21s.*)

This, the latest edition of a book first published some thirty years ago, has been largely rewritten and includes additional standard engineering data, including British Standards.

The first section of the volume covers the art of draughtsmanship, methods of projection, and the production of pictorial views. It then proceeds to discuss, in a sequence impossible to define, the design of familiar basic engineering details. Couplings, connecting rods, bearings, cottered joints, keys and keyways, etc., are all dealt with in turn as isolated components, with little reference to the overall design of any machine in which they might be used.

Each section is followed by exercises in design calculations (with answers), and in the production of working drawings from the pictorial views given. For the student working alone the latter are of little use, since there is no means of checking the final result.

The only reference to really modern practice is in the small section devoted to aircraft details. Here, the design of bolted lugs, rivet groups, a shackle fitting and a control lever are treated briefly in the manner which prevails throughout the book. In an attempt to cover as wide a field as possible, there is a failure to discuss sufficiently the design problems associated with any one of the many varied items.

Commendable are the many illustrations, almost all pictorial views, and the numerous worked examples of simple stressing cases.

Part 2 of the book consists entirely of exercises from past examination papers, arranged in ascending order of difficulty. This is followed by a short data appendix.

Possibly a useful addition to the student's library in his intermediate days, but with the rising standards of modern technical education not quite up to the level for which it was originally intended.

R. B. Selwyn

Progress in Cryogenics: Vol. 2. *Edited by K. Mendelssohn.* (*Heywood & Co. Ltd.—63s.*)

To the student and expert alike, the study of developments in the deep low-temperature field is of absorbing interest, demanding a new concept of the application of materials, of which the properties and behaviour in most cases undergo significant and often important changes. The everyday use and distribution of liquefied atmospheric gases (at temperatures around −200 deg. C.), and more recently the availability of liquid hydrogen (−253 deg. C.) and liquid helium (−269 deg. C.), have led to rapid advances in the discovery and application of these new properties in diverse fields.

The second volume of this series maintains the high reputation created by the first, and contains eight contributions (each by recognised authorities in their subjects), including storage and handling of cryogenic liquids, the gas refrigerating machine, low-temperature bubble chambers, and the three-level solid-state maser.

The editor has exercised sound judgment in his balanced selection of subjects, and by careful control of presentation he has made it possible to readily understand the progress in each specialised field of activity contained in this volume. Copious references are provided to enable more detailed study to be made on particular points. Both volumes are of outstanding value for reference purposes.

Practical considerations are given their full relationship to theoretical progress, and both engineer and scientist will be well rewarded by a study of this series of important works.

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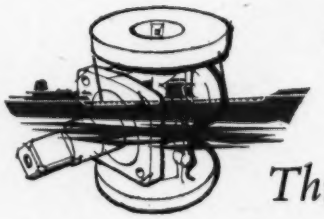

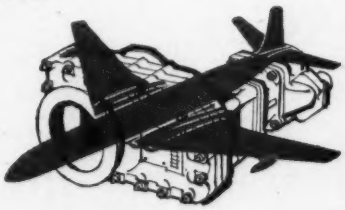

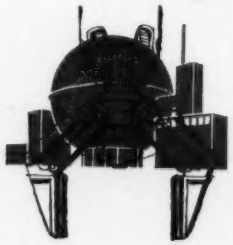

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LETTERS TO THE EDITOR

Sir,

We recently received a copy of your August article on our recently introduced thermoelectric generator. Your comment that, "even so, the cost per kW. will still be more than 100 times that of present nuclear power stations" is an unfair standard of comparison. Thermoelectric generators of this type are for those applications where commercial power (nuclear or non-nuclear) is either unavailable or difficult to obtain. We make no claim that thermoelectric generators can compete economically with large central power stations. We feel that this distinction is an important one and perhaps will be worthy of note to your readers.

Howard Hagler

General Instrument Corp.,
65 Gouverneur Street,
Newark, 4,
N.J.,
U.S.A.

New developments of this type often tend to be exaggerated, particularly in respect of applications. Perhaps we have over-emphasised the point, but our object in making this comparison was to put the present stage of development of the thermoelectric generator in its true perspective.

Sir,

We have read with interest the article on metallic bellows in your October issue, but we were very disappointed that our name was not included on page 621 in the list of principal manufacturers. You will, no doubt, be interested to know that we manufacture a large range of Genflex bellows expansion joints, and are supplying them for a great variety of applications to the leading engineering firms in this country, including diesel locomotive and nuclear concerns. We have been manufacturing this type of equipment since May 1960, and have gained a very high reputation for first-class design and workmanship in this particular field.

A. E. Rutter

Vokes Genspring Ltd.,
Henley Park,
Near Guildford, Surrey.

Sir,

I was very impressed with the comprehensive survey you have published on process timers (p. 554, September). The article is really very good, particularly as it is on such a specialised subject, and the only comments I can make are of a relatively minor nature. They are:

(a) At the top of the second column of page 556 the article refers to the effect of the interruption of supply to self-resetting timers. Some designs of timers hold their setting on mains failure and resume from where they left off when the mains are restored, but it is more usual to have the drive transmitted via a clutch which is closed while the coil is energised, and thus the usual timer resets on mains failure. This can be prevented by having a d.c. clutch fed from a small battery. It is most important to let the timer manufacturer know the type of action required on mains failure, e.g., immediate reset, or remaining at the stage reached at the time of mains failure. There is also the question as to whether the process is to restart automatically or not when the mains are restored.

(b) Regarding motor starting times, shaded pole motors, such as those made by Rodene and Everitt Edgecombe, reach full speed within about two cycles of the mains supply and can thus be regarded as instant starting in almost every case. A further important factor is that this type of motor can be left stalled without harm, whereas if the type with rotating magnet are left stalled they can become demagnetised.

(c) Very few users realise that a normal auto-resetting timer should not be connected to restart automatically, as a finite time must be left for the timer to come to rest before it is restarted in the opposite direction; if this is not done the result can be similar to engaging forward speed in a car while it is still moving in reverse. If quick and automatic restarting is required, it is usually necessary to have a subsidiary timing device to measure out the reset time.

D. Robinson

D. Robinson & Co. Ltd.,
Gunnersbury House,
717 London Road, Hounslow, Middlesex.

Sir,

We are delighted to see that your magazine has once again given space to two features on plastics, in your issue of October 1960. We would like to comment on these two articles, particularly on the one entitled "Zinc Die Castings Versus Plastics Mouldings".

We feel that this article is slightly out of focus, and therefore gives a somewhat distorted picture. Reference is made in the article to phenol formaldehyde moulding powders, cellulose acetate moulding powders, polystyrene moulding powders and others, but no reference is made to the two, or perhaps three, plastics which really matter in an article under this title—namely, nylon, polyformaldehyde (or polyacetyl if you prefer) and perhaps polycarbonates.

Closely allied to, and indeed responsible for, the comment we have made above is the fact that no reference is made throughout the article to what is normally regarded as the one great failing of plastics, namely that they have a low modulus, or to the equally important fact that the properties of plastics must be viewed as a whole. A striking illustration of this is that although nylon has, compared with metals, a relatively low modulus, yet by taking advantage of the fact that it also has a high measure of flexibility it becomes possible to design from it admirable gears which can give superior service to comparable ones made from metal. Here, the essential design point is that the flexibility of the plastics permits the load on the gear to be spread over quite a large area, thus reducing the pressure loading to well within the limits that the plastics can tolerate.

We also think that tables such as 1 and 3 in the article are very misleading indeed unless the test methods are specified, and in particular we are not at all sure that it is justified to draw any such conclusions from Table 3 as are drawn in the text.

Turning to more specific comments, in the fourth paragraph of the first column on page 622, reference is made to the fact that "the price of plastics moulding powders—other than the general-purpose thermosetting type—is relatively high, compared with that of zinc die casting alloys". This statement is extremely limited in its scope, as, when account is taken of the difference in specific gravity and the simplicity of fabrication with plastics (including the absence of finishing operations compared with those that are necessary with metals), the price picture for a finished article is often very much in favour of plastics.

Under the same heading of "Injection Moulding", on page 623, reference is made to the moulding in America of articles of a weight of 2 lb., and in this country of mouldings with a weight of 1 lb. We are not in a position to be able to tell you the maximum weights of articles which have been moulded either in this country or America, but can tell you that machines with a rated capacity of 480 oz. of polystyrene have been used in America, and that machines of at least 160 oz. capacity are in use in this country. We are quite sure that even the 160-oz. machines in this country have turned out mouldings weighing very considerably more than 1 lb.

In the first two lines of the left-hand column on page 624 reference is made to water absorption which may occur with moulded plastics other than polystyrene. We think that the question of water-absorption should be dealt with somewhat more fully than is done in the article which, at the moment, could mislead designers who are not familiar with plastics and who might get the impression from what is said in the article that plastics go mouldy. Also, if an exception is made of polystyrene, then by the same token polythene and polypropylene at least should also be excluded from the general statements made.

Finally, the last paragraph of the article as worded gives the designer who is not familiar with plastics the impression that plastics are useful merely for ornamental purposes. Few people would, we imagine, deny that in general plastics are far more beautiful to look at than are zinc die castings, but any increase in visual appeal is, in a properly designed and engineered plastics moulding, only something that is added to a product which is already superior to a zinc die casting.

P. I. Smith

I.C.I. Plastics Division,
Welwyn Garden City,
Herts.

HEAT LOSS IN MATERIALS

Engineering Materials and Design
DATA SHEET No. 50

Heat loss = Heat flow =
$$\frac{\text{Temperature difference above ambient (deg. F.)}}{1/f + t/k} \text{ (B.t.u./sq. ft.hr.)}$$

where f = Surface coefficient (B.t.u./sq. ft. hr. deg. F.).

Empirical solutions are as follows:

Flat surface facing upwards—$f = 1{\cdot}67 + (0{\cdot}007 \times \text{temp. diff.})$
Flat surface facing downwards—$f = 1{\cdot}3 + (0{\cdot}006 \times \text{temp. diff.})$
All vertical surfaces—$f = 1{\cdot}4 + (0{\cdot}007 \times \text{temp. diff.})$
Horizontal pipes—$f = 1{\cdot}45 + (0{\cdot}007 \times \text{temp. diff.})$
Vertical pipes—$f = 1{\cdot}4 + (0{\cdot}007 \times \text{temp. diff.})$

t = Material thickness (in.).
k = Thermal conductivity of material (B.t.u./sq. ft. in. hr deg. F.).

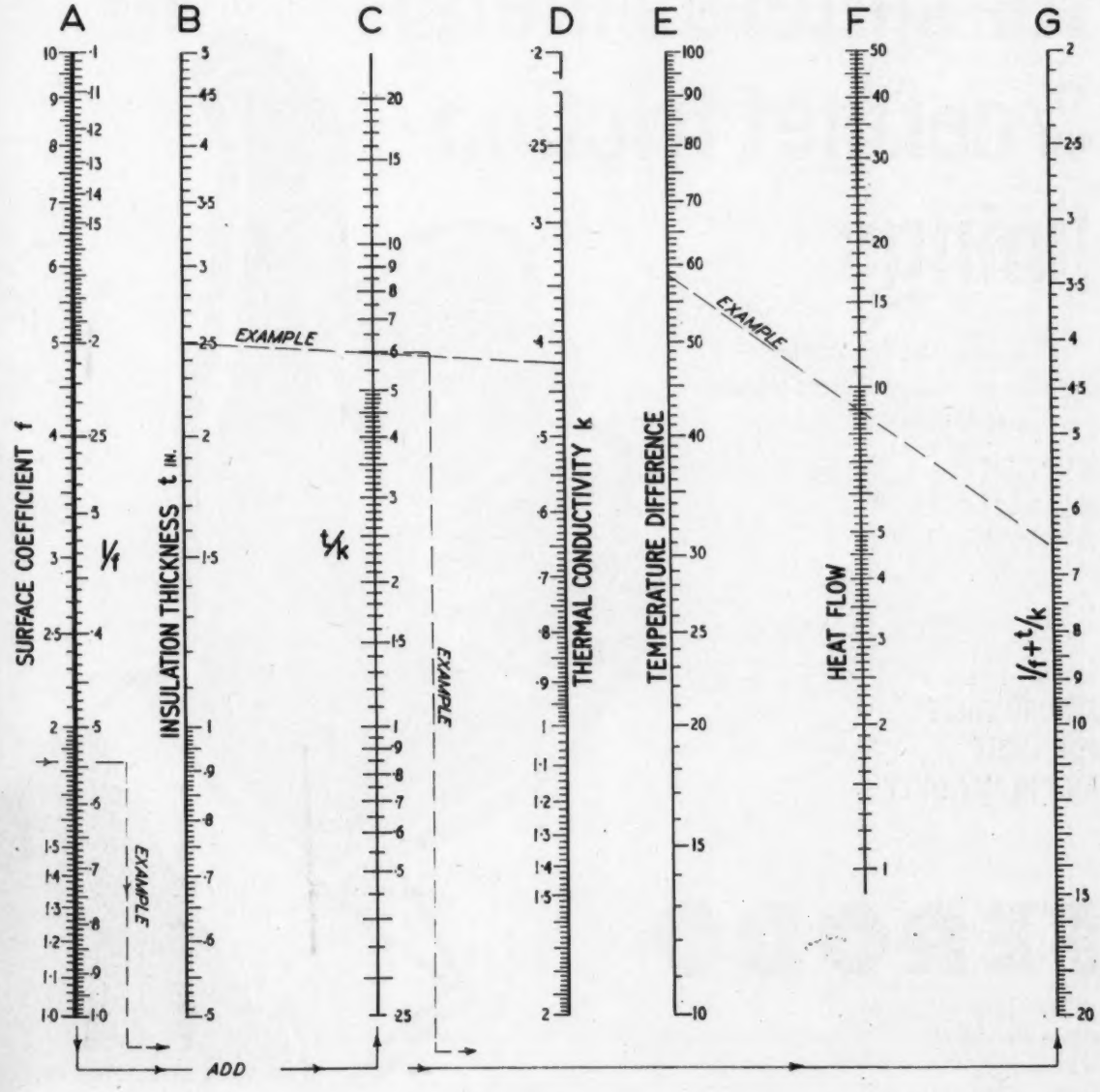
(1) The nomograms can be worked in either direction, depending on the unknown, but they must be used separately (they cannot be linked other than by transfer of the quantity) (1/f + t/k).

(2) Heat flow is directly proportional to temperature difference; therefore this scale can be factored, as necessary, to accommodate higher values.

Example

Given f = 1·84, thickness of insulation = 2½ in., k = 0·42, hot face temperature = 650 deg. F., and ambient temperature = 65 deg. F. Find the heat loss.

(a) Use scale A to find 1/f from f, e.g., 1/f = 0·54.
(b) Use scales B, C and D to extract t/k, e.g., t/k = 6·0.
(c) Add 1/f and t/k and insert in scale G, e.g., 6·0 + 0·54 = 6·54.
(d) Join point on scale G to temperature difference on scale E, and in this example factor answer by 10 (see note 2), e.g., 650 − 65 = 585, which factored by 10 = 58·5 (scale E).
(e) Read off answer on scale F and factor in this example by 10, e.g., 9·0, which factored by 10 = 90·0.



EMD 4213 for further information

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STEELS FOR INVESTMENT CASTINGS

Engineering Materials and Design
DATA SHEET No. 51

The BS 3100 series of specifications covers all existing British standards for steel castings for conventional steel foundry working. Due to difficulty experienced by investment castings foundries when working to these specifications, BS 3146 was issued, the aims being: (a) to include those alloys which had not previously been covered; (b) to establish a more realistic base for a chemical and analytic design; (c) to omit those alloys which were unsuitable for investment casting; and (d) to unite all investment casting alloys in one series of specifications.

Where a material in specification BS 3146 is directly comparable to a material in BS 3100, the relevant specification has been included in the last column of the table.

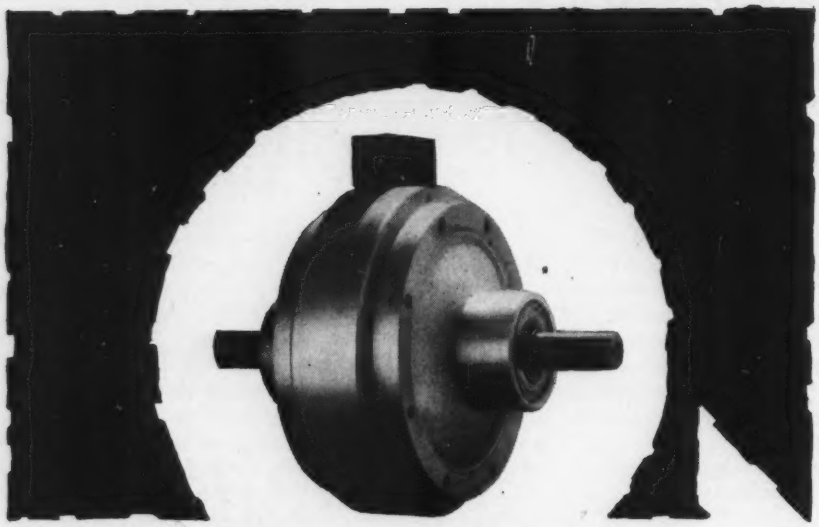
The responsible B.S.I. Committee is now engaged in drawing up Part 2 of BS 3146, which is expected to cover 13 per cent chromium 18/8 austenitic steels, and ferrous, nickel, and cobalt-base creep and corrosion-resistant alloys. With the growing demand for standards for investment-cast copper and aluminium-base alloys, it is likely that these will in the future be included within the BS 3146 standard for investment castings.

One danger to be guarded against is that of new alloys being put forward for standardization on a too limited basis of experience of their castability, and the metallurgical problems involved in producing sound castings. This is particularly so when materials appear to offer properties which appeal to designers.

British Investment Casters' Technical Association

Summary of Steels in BS 3146, Part 1: 1959

Specn.	Grade	Type of steel	Chemical Composition (per cent) (Maxima, unless otherwise stated)									Properties			Comparable to specification in series BS 3100
			C	Si	Mn	Ni	Cr	Mo	Cu	S	P	Tensile strength (min.) (t.s.i.)	El. (min.) (%)	Izod (ft. lb.)	
CLA 1	A	Carbon steel	0·25	0·60	1·00	0·40	0·25	0·15	0·30	0·050	0·050	28	22	—	BS 592
	B		0·35	0·60	1·00	0·40	0·25	0·15	0·30	0·050	0·050	32	20	—	(Properties only)
	C		0·45	0·60	1·00	0·40	0·25	0·15	0·30	0·050	0·050	35	15	—	
CLA 2	A	1½% Mn steel	0·18-0·25	0·50	1·20-1·70	0·40	0·25	0·15	0·30	0·050	0·050	35-45	18	25	BS 1456
	B		0·25-0·33	0·50	1·20-1·70	0·40	0·25	0·15	0·30	0·050	0·050	45-55	15	20	(Properties only)
CLA 3		45-55 ton alloy steel	—	—	—	—	—	—	—	0·050	0·050	45-55	15	25	BS 1458
CLA 4		55-65 ton alloy steel	—	—	—	—	—	—	—	0·050	0·050	55-65	12	15	BS 1459
CLA 5	A	High tensile steel	—	—	—	—	—	—	—	0·020	0·025	60	12	30	—
	B		—	—	—	—	—	—	—	0·020	0·025	75	7	10	
CLA 6		Carbon Mo steel	0·15-0·25	0·20-0·50	0·50-1·00	0·40	0·25	0·40-0·70	0·40	0·050	0·050	30	20	15	—
CLA 7		3% Cr Mo steel	0·25	0·75	0·30-0·60	0·40	2·50-3·50	0·35-0·60	0·40	0·050	0·050	40-50	18	25	BS 1461
CLA 8		Carbon steel. Surface hardening	0·35-0·45	0·60	0·50-0·80	0·40	0·25	0·15	0·40	0·050	0·050	35	15	—	—
CLA 9		Carbon steel. Case hardening	0·10-0·18	0·25-0·60	0·60-1·00	0·40	0·30	0·15	0·30	0·050	0·050	32	20	20	—
CLA 10		3% Ni. Case hardening	0·10-0·18	0·25-0·60	0·30-0·60	2·75-3·50	0·30	0·15	0·30	0·050	0·050	45	18	30	—
CLA 11		3% Cr Mo steel	0·20-0·30	0·25-0·75	0·30-0·60	0·40	2·90-3·50	0·40-0·70	0·40	0·045	0·045	55-65	12	15	—
CLA 12	A & B	1% Cr steel	0·45-0·55	0·75	0·50-1·00	0·40	0·80-1·20	0·15	0·40	0·050	0·050	45	10	—	BS 1956
	C		0·55-0·65	0·75	0·50-1·00	0·40	0·80-1·50	0·20-0·40	0·40	0·050	0·050	—	—	—	(Properties only)



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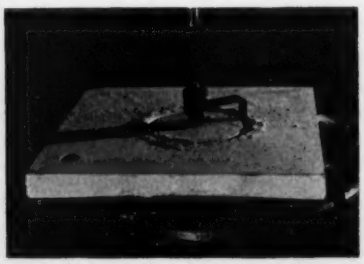
Cromate Pretreatment

A chromate conversion process called Cromcote, for the treatment of aluminium and its alloys, is claimed to produce a chromate coating with a high corrosion resistance value and excellent paint-bonding properties. It is also claimed to have a low electrical resistance, so that the process can be used on parts for electrical equipment. The solution must be contained in an acid-resisting tank of stainless steel, plastic-lined mild steel, or fibreglass, and it is normally operated at room temperature. Parts to be treated should be free from grease, and immersion times vary from 10 sec. to 5 min. according to the colour required—this varies from almost colourless to deep bronze, the corrosion resistance generally increasing with depth of colour. The Walterisation Co. Ltd., Purley Way, Croydon.

EMD 4283 for further information

Machinable Refractory

Zirconite is a true ceramic, comprising high-purity zircon in an easily workable form, and can be sawn, drilled, filed, turned and shaped. Costing around 3d./cu. in., it is said to be the ideal material



for the furnace designer and engineer, laboratory technician and high-temperature worker—thermally, it takes over where conventional asbestos-based materials stop. It is available in handy stock billets—rounds. squares and slabs—or tailored to customers' drawing. There is also a Zirconite cement and a Zirconite castable. W. & C. Spicer Ltd., The Grange, Kingham, Oxon.

EMD 4284 for further information

Stainless Steel Paint

Vita-Var stainless steel paint is a multi-pigment paint of which stainless steel flake (18 per cent Cr, 8 per cent Ni) is the principal pigment, blended with several non-metallic pigments in an oil/alkyd/resin vehicle. The stainless steel flakes form a tough protective armour plate on the painted surface. The paint becomes lighter and more metallic in appearance after two years of exposure, this attractive finish being retained due to its corrosion-resisting properties and dust-collection resistance.

It is claimed that the paint gives twelve years' protection, as compared to six years by the best conventional industrial two-coat systems, and that great savings, approaching £1,000 per year, can therefore be achieved where 1,000 gallons or more of top-quality conventional paints are normally used per year. Anthony Edwards & Associates, 57 Talgarth Road, London, W.14.

EMD 4285 for further information

Mild Steel Electrodes

Two new additions to a well-known range of arc-welding electrodes have recently been introduced. The first of these, NuFive, is a smooth-flowing mild steel electrode of the cellulose type, designed for the welding of mild steel in all positions, using a.c. or d.c. It gives good penetration qualities, and with its high melting rate and readily controlled slag is particularly suitable for pipe welding, using either the conventional or "stove-pipe" techniques. The electrode, which conforms to the requirements of BS 639: 1952, is approved by Lloyd's Register of Shipping and the Ministry of Transport for the welding of mild steel in all positions. The British classification for NuFive is E.111 (BS 1719), the American classification being E.6011 (A.W.S./A.S.T.M.).

The other new addition is NuSeven, an electrode of the iron powder/rutile type for general application to the welding of mild steel in all positions. A higher deposition efficiency compared with conventional titania (E.317) type electrodes, with a faster deposition rate and less sticking of the electrode, are amongst the advantages claimed for NuSeven, enabling up to 30 per cent more weld per electrode to be obtained, thus giving more arc time and so reducing production costs. Good

slag control is said to render positional welding easier, and in many applications the slag is self-releasing. NuSeven electrode is approved by Lloyd's Register of Shipping and the Ministry of Transport for the welding of mild steel in all positions. Its classification under British Standard 1719 is E.917, the American classification being E.6014 (A.W.S./A.S.T.M.). Lincoln Electric Co. Ltd., Welwyn Garden City, Herts.

EMD 4286 for further information

Anti-corrosion Primer

A new material has been produced which is claimed to bridge the gap between ordinary paints which seek to prevent rust by purely physical means, and anodic metal coatings with all their advantages of physical durability and their high degree of electro-chemical (cathodic) protection. Known as Anogal, it is essentially a paint-like material which is applied in exactly the same way as paint, but it has a marked electro-chemical reaction with steel, and possesses when dry all the electro-chemical properties of an anodic metal coating applied by conventional methods. It has a battleship-grey matt finish.

The properties of adhesion, flexibility, resistance to mild chemical attack and compatibility with all known finishing materials of this new material are said to be far higher than in other materials of this type, because of particular differences in formulation and make-up.

Anogal has a heat resistance to 285 deg. C., and is made in a semi-thixotropic state with good flow properties. Very little settlement is noticed, even after long storage. It is specially suited for application to large structures which cannot be conveniently metallised by any other methods, and at the same time is said to be far cheaper than conventional methods of metallising. Corrosion Prevention Ltd., Welford House, 8 Victoria Avenue, Harrogate, Yorks.

EMD 4287 for further information

New Nimonic Alloy

Nimonic 115, which is an addition to the Nimonic series, is claimed to show a considerable increase in operating temperature compared with the figures for the previous alloy (Nimonic 105), together with a 50 per cent increase in creep life. It is released against a test specification of 7 t.s.i. at 980 deg. C., with a life to rupture of 75 hr. minimum.

The development of the alloy has been associated with a possible test requirement of 35 hr. to rupture at a stress of 7 t.s.i. at 1,000 deg. C., and although production quantities are not yet released against this criterion, the test target is a further indication of the level of properties offered. Nimonic 115 alloy is now being supplied to several engine builders, and is already used for the blades of certain of the most advanced gas-turbine engines. Henry Wiggin & Co. Ltd., Thames House, Millbank, London, S.W.1.

EMD 4288 for further information

Please Note!

We receive many reader enquiry cards on which the reader has omitted to fill in his name and address. In order to avoid disappointment we remind readers that names and addresses should be included on *each* card.

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Magnesium Elektron, Inc., New York 20, USA

Precision Diamond Paste

A new precision diamond paste, X-17, manufactured in Switzerland is now available in this country. The diamond grains in the paste, which is available in twelve different grain sizes, are very accurately sorted for size and shape, enabling each grain to be a working grain and avoiding irregular scratching from oversized and misshapen grains. Since all the grains are working grains, the paste is economical and quick to use, reductions in time of up to 90 per cent compared with other methods being claimed.

X-17 is supplied in 5-gm. sealed glass syringes for economy in use and freedom from spoilage by foreign matter. The twelve different grain sizes are easily identifiable by their distinctive colours. It is suitable for use with cemented carbides, all hardened steels, unhardened steels, stainless steels, cast iron, brass, copper, other non-ferrous metals, gems, etc. It is used in general machine construction, toolmaking (deep drawing materials), gauge making, in the paper industry, film industry (rolls), and in automobile building (valves, crankshafts, fuel injection components, etc.). Charles Churchill & Co. Ltd., Coventry Road, South Yardley, Birmingham.

EMD 4289 for further information

Non-fluff Paper

Kimwipes are a new product designed as a general-purpose disposable wiper, for use throughout a wide range of industries and trades. They are packed 100 to a self-

dispensing carton. Uses range from cleaning light machinery, precision tools and instruments, to polishing glass and plastics products, and from cleaning where the use of a solvent is involved to mopping-up spills in bottling operations. Kimwipes are claimed to give a completely dust- and fluff-free finish, and to be highly conformable. Kimberly-Clark Ltd., Larkfield, Maidstone, Kent.

EMD 4290 for further information

Inorganic Plastics

Astrasil is the trade name of a resin-bonded laminate or moulding of Refrasil cloth impregnated with a phenolic resin (Refrasil is a virtually pure silica fibre). Refrasil reinforced plastics have been available in the United States for some time, and their remarkable physical properties have been recognised and utilised by missile engineers for the construction of nose cones, combustion chamber liners, blast tubes, nozzle components and deflector vanes.

Co-operation between British Refrasil Co. Ltd. and Microcell Ltd. has now made possible the production of Astrasil in the U.K. It is available as pre-impregnated cloth from which laminates can be produced by vacuum and press moulding techniques. It can also be supplied in the form of close tolerance mouldings and accurately machined parts to customers' designs.

The laminates are said to give continuous service at temperatures up to 260 deg. C., but in most of the applications for which they are used, temperatures are so high that all materials have a very short life. In a 2,480 deg. C. burn-through test, the laminate is claimed to perform better than a stainless-steel plate of the same thickness by a factor of more than three to one, and on a weight basis this factor becomes fifteen to one. British Refrasil Co. Ltd., Stillington, Co. Durham.

EMD 4291 for further information

Adhesive-coated Aluminium

Plymaster ACA-1050 is an adhesive system consisting of aluminium foil or sheet which has been pre-coated with a 100 per cent solids specially-formulated structural adhesive. It was originally developed for lightweight, non-load-bearing sandwich panel manufacture in the aircraft industry, where it is said to have the following features: Excellent peel strength; excellent filleting properties; superior shear and compressive strengths; greater ease of handling (no metal cleaning, no mixing, minimum toxicity, no core preparation, storage at room temperature); lighter weight bonded assemblies; and lower overall costs.

It is at present produced in roll form in widths up to approximately 48 in., and lengths up to approximately 400 ft. Currently available material consists of 5052 full hard aluminium alloy in nominal foil thickness of 4 mil. or 8 mil., coated to an adhesive weight of 0·028 ±0·002 lb./sq. ft. Omni (London) Ltd., 35 Dover Street, London, W.1.

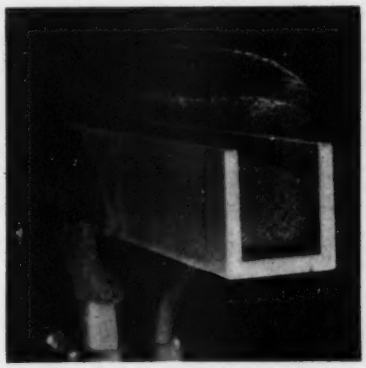
EMD 4292 for further information

Expanding Sealer

EC-1817-A is a pumpable mastic sealer. It is designed to expand and cure to a resilient sponge which adheres to most surfaces, and also designed to function as a weld-through sealer which does not alter normal welding procedure, nor interfere with weld quality.

In seams where irregular openings must be filled, or where the seam width is not constant, this sealer expands on curing to tightly fit the shape of the seam. It is recommended for the automotive industry, to seal spot-welded joints where some buckling of the metal occurs during the welding operation. A typical example would be sealing the joint where the floor pan is welded to the quarter panel. It is cured during the usual paint bake cycle, and no added curing step is required. The swelling which results is said to ensure a weather-tight, water-tight, dirt-tight seal.

As a pumpable sealer, the material is claimed to offer advantages over pre-formed solid extruded sealers in many



applications, and to be readily adapted to production techniques. The desired size and shape of sealer bead can be quickly applied to the usual flow gun, and rapid changes in bead size and shape can be made by changing the flow gun tip.

EC-1817-A contains no solvent, and therefore there should be no toxicity problem or fire hazard during storage or application, nor any shrinkage problem due to solvent loss. When tested in a Cleveland open cup, the material is claimed not to flash below 150 deg C. Minnesota Mining & Mfg. Co., 3M House, Wigmore Street, London, W.1.

EMD 4293 for further information

Hypalon Paint

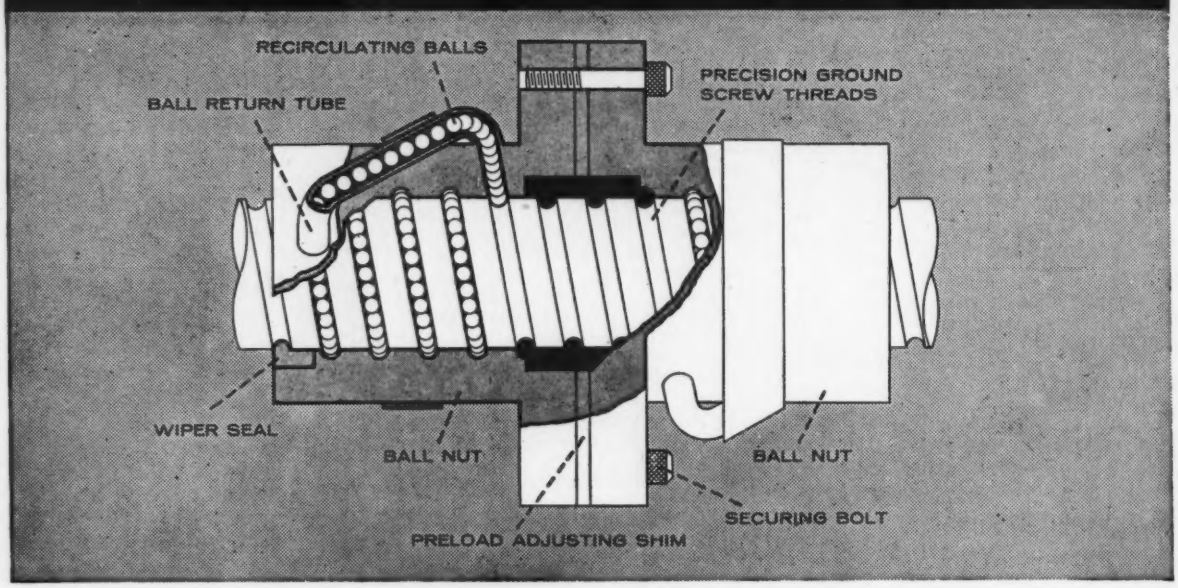
A new, versatile, liquid coating having elastomeric properties is announced. This product, selling under the registered name of Texseal, is a recent development of the Chemical Products Division of the Dunlop Rubber Co., and is based on Hypalon synthetic rubber, a product of E. I. Du Pont de Nemours & Co. Inc.

The important properties offered by Texseal result from the outstanding properties of Hypalon, a chlorosulphonated polyethylene, which has been formulated with various other ingredients. Principal among these properties, it is said, are chemical and ozone resistance, and hence an important field of application is that of the corrosion protection of chemical plant and structural steelwork, particularly in marine installations.

Texseal is also claimed to have good flame resistance, and to be suitable for continuous service at temperatures up to 120 deg. C. It can be satisfactorily applied to a variety of substrates, such as concrete, steel, fibreboard, wood and rubber, with good adhesion between the coating and base material. Its application is similar to that of other paints, in that it can be brushed, sprayed or applied by dip and spread coating. Vicsteels Ltd., Craven House, 16 Northumberland Avenue, London, W.C.2.

EMD 4294 for further information

Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



...ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of −52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

** Complete technical and manufacturing co-operation with Beaver Precision Products Inc., Detroit.*

For further information please write to J.B. Starky, Sales Manager (Ball Screws and Splines), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED

Wax Element Thermostat

These units are designed to give a positive temperature control for all types of internal combustion engines, and they are said to be insensitive to pressurisation, unaffected by vibration, and to have a long operational life. They can be supplied at start-to-open temperature settings from 85-185 deg. F., in either by-pass or non-by-pass type units. They can also be used for operating relief or diverter valves in hydraulic or pneumatic systems. Western Thompson Controls Ltd., The Aerodrome, Reading, Berks.

EMD 4295 for further information

Hydraulic Motor

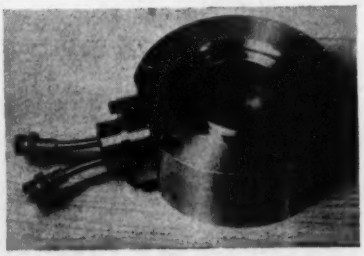
This motor consists of a bronze cylinder block in which are housed seven radially disposed pistons. The cylinder rotates around a hardened steel distributor stalk, and the pistons bear against a circular track which is positioned eccentrically to the centre of the stalk. Thus the pistons travel in and out as the cylinder block rotates. Maximum speed is 20,000 r.p.m., and maximum pressure is 1,000 p.s.i. The displacement per revolution is 0·106 cc. An output torque at 1,000 p.s.i. inlet pressure and 20,000 r.p.m. is 700 gm. cm. Boulton Paul Aircraft Ltd., Wolverhampton, Staffs.

EMD 4296 for further information

High Conductance Baffles

CB2 cold baffles have been designed for use with Speedivac 2-in.-bore oil and mercury diffusion pumps. These high conductance baffles are normally employed for applications requiring a constant high vacuum, or for incorporation into ultra high vacuum systems, where they are used in a similar manner to the refrigerated chevron baffles supplied with the larger diffusion pumps.

The body of the CB2 is constructed from stainless steel, and is provided with six stud holes for attachment to the top flange of the diffusion pump. A circular baffle forms a part of the welded interior of the baffle, and clamped to the underside of this plate is a single cooling coil through which can be circulated water



as a cooling medium, or other heat transfer fluids and refrigerants. The use of the latter will enable the pump to reach high vacua. Screwed connections are fitted to the cooling coil, which enters the baffle body through an assembly flange fitted with a permanent metal gasket seal.

For normal use the CBO2 is supplied fitted with an O ring seal on the top flange. For ultra high vacuum use, however, and for bakeable systems, the CBA2 is recommended, which has a plain top flange with no O ring groove, the seal being made with an aluminium wire gasket. Edwards High Vacuum Ltd., Manor Royal, Crawley, Sussex.

EMD 4297 for further information

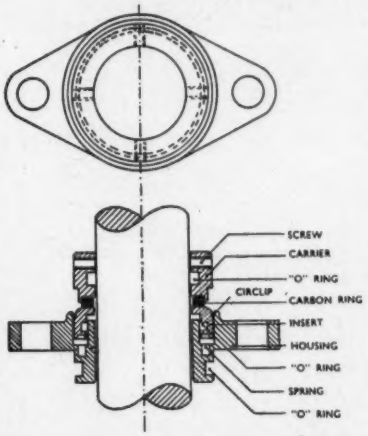
Hand-set Synchronous Timer

Timer type NHR has a new internal mechanism. It retains the front panel and fixing positions of the old timer, type HR, and utilises continuously adjustable timing cams. The standard timer is fitted with one or two changeover microswitches, but up to twelve timed circuits and twelve changeover switches can be provided. Switching capacity is 6 amps at 230 volts a.c., and time ranges are between 0-30 sec. and 0-12 days. Electrical Remote Control Co. Ltd., The Fairway, Bush Fair, Harlow, Essex.

EMD 4298 for further information

Mechanical Seals for Volatile Liquids

The J.6 range of mechanical shaft seals has been developed for handling petroleum products and other volatile liquids. A particular advantage claimed for the seals is that they are capable of running continuously in a dry condition, as may



sometimes unintentionally occur, without overheating. It is claimed therefore that the seals are particularly suitable for drawing volatile spirits from barges, and for other applications where temperature rise at the seal faces or power absorption is important. The J.6 range can be supplied for external or internal fitting, as a self-contained unit requiring neither lubricant nor coolant. J. A. Cannings Ltd., Bathwick, Bath, Somerset.

EMD 4299 for further information

Time Indicator

A series of compact, electro-chemical, elapsed time indicators have been introduced for recording the total operation time of electrical equipment.

These new indicators, known as the Selachron range, have been designed in forms suitable for either a.c. or d.c. operation, and in sizes for use with voltages of from 6-300 volts, thus obviating the need for any extra switches or relays and allowing them to be wired to the terminals of the equipment being timed. The indicators use no moving parts and consist of cartridges which contain small, replace-

able electro-chemical cells, embodying an anode, cathode and electrolyte. The anode is consumed as current passes through the cell, the length diminishing in proportion to the accumulated hours of operation, this being shown by a calibrated scale alongside the anode.

The length of each indicator is 2¼ in., the diameter being 1 in. The weight is less than 2 oz. Industrial Instruments Ltd., 9 Paved Court, Richmond, Surrey.

EMD 4300 for further information

Worm Gear Units

A new range of Radicon worm gear units covers centre distances from 1¼-8 in., and is of two basic types, the Adaptable for distances 1¼-3¾ in. and the Solid Foot for centre distances of 4-8 in. The first range covers seven sizes, and is suitable for up to 10 h.p. Detachable feet enable a number of different mounting positions to be obtained. Further improvements include external ribbing of the case, and a cooling fan to increase heat dissipation.

The Solid Foot units are in five sizes in three basic types covering requirements up to 80 h.p. These units are interchangeable with Radicon units of previous design. David Brown Corp. (Sales) Ltd., Park Works, Huddersfield.

EMD 4301 for further information

Data Sheet No. 39 (June 1960)

Our attention has been drawn by the Aluminium Development Association to the values aligned with aluminium and aluminium alloy on the Modulus of Elasticity scale. The values recognised by the Association lie within the range 9·9 to 10·5 $\times 10^{-6}$ p.s.i. for both these materials.

EMD 4217 for further information

50,000

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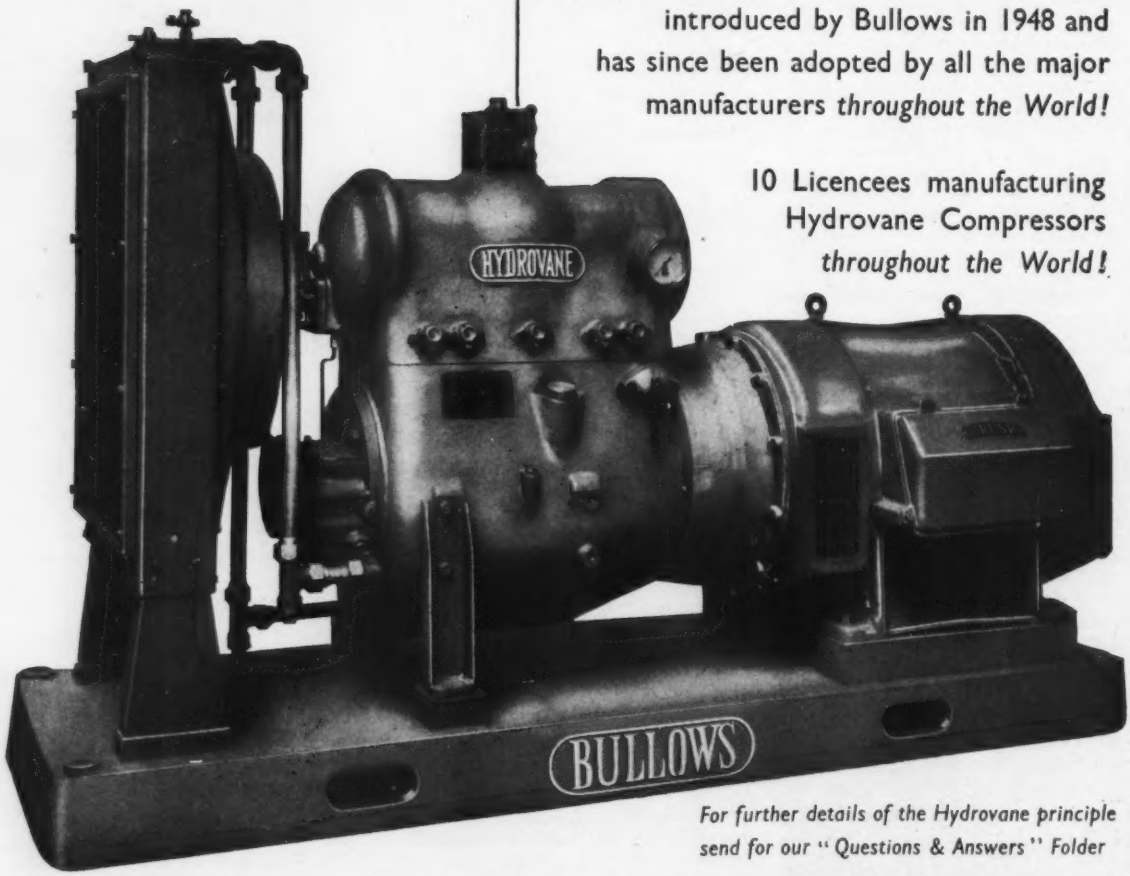

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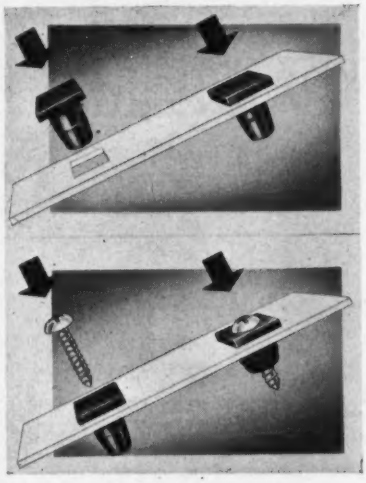
BULLOWS (AUST) PTY. LTD., ETHEL AVENUE, BROOKVALE, SYDNEY, AUSTRALIA.

Nylon Fastener

Injection moulded in type 66 nylon, the Insulgrip fastener is claimed to be a tough, shakeproof and virtually indestructible form of anchorage that is of particular value where fastening access is limited to one side of an assembly.

Two types are currently available: Type 1 utilises an underhead square engaging in a preformed square hole to



prevent rotation during the thread-forming and collapsing phase, for general applications in all industries; Type 2 relies on two preformed round holes for anti-rotational and anchorage purposes, and is designed particularly for use in the electrical industry, where large insulation surfaces are required or where it is impracticable to form a square hole.

The Insulgrip principle is very simple to employ, and requires no special assembly tools: (a) insert into suitably formed hole—the specially designed projections clip the fastener in position and lead the product correctly into the hole, thus minimising a common assembly hazard; (b) screw in an N.P.K. self-tapping screw and the Insulgrip will collapse to form a firm fixing—the screw can be replaced any number of times, the assembly remaining fast. George Goodman Ltd., Robin Hood Lane, Hall Green, Birmingham, 28.

EMD 4302 for further information

Miniature Circuit Breaker

This circuit breaker, type C-50, has an electro-magnetically operated tripping mechanism, and all ratings are set to trip at a maximum overload of 30 per cent. A built-in inverse time-current delay device is said to prevent harmless transient overloads from causing unnecessary tripping, but the same mechanism will give protection under heavy overload or short-circuit fault conditions. The minimum tripping current is said to be unaffected by variations in ambient temperature.

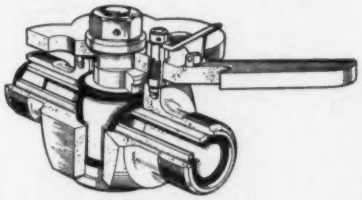
These units are claimed to have a number of advantages over fuses, in that they cannot be over-fused unintentionally, the supply can be restored as soon as the fault has been cleared, and there is no deterioration with age. J. A. Crabtree & Co. Ltd., Lincoln Works, Walsall, Staffs.

EMD 4303 for further information

New Valve uses O Rings

The Peckett Orseal valve depends for its action on O rings used in a novel manner. The valve consists of a cylindrical valve working in a cylindrical bore with a clearance space in which the O rings are inserted. At either end an O ring surrounds the plug, thus providing a seal against leakage to atmosphere. The inlet and outlet passages are carried through spigots which project into the annular clearance space with the ends shaped to envelop the cylindrical surface of the plug, but with a small clearance between them and the plug. Surrounding each spigot is an O ring, which also conforms to the radius of the annular space instead of lying in a flat plane. In operation, the working fluid under pressure leaks past the O ring on the inlet spigot and fills the annular space, thus closing the O ring on the outlet spigot and forming a seal between it and the cylindrical plug.

The advantages claimed for the Orseal valve are: bubble tight under vacuum and pressure; smooth full-bore passage; no



lubrication, except in special cases; simple construction due to the use of a cylindrical plug; and negligible maintenance—the valve is restored to new condition by fitting new O rings, an operation said to be possible in 1 min. without taking the valve out of the line.

These valves are at present available for hydraulic systems up to 1¼ in. nominal bore size, for a working pressure of 3,500 p.s.i. in forged steel. Gunmetal valves up to 2 in. bore are for pressures up to 500 p.s.i., and cast-iron valves from 3 to 8 in. bore are for pressures of 250 p.s.i. Peckett & Sons Ltd., Atlas Works, St. George, Bristol, 5.

EMD 4304 for further information

Shaded Pole Motor

A new range of shaded pole skeleton frame motors (the P range) has been introduced. Twelve different models are available for both 50 c/s and 60 c/s supplies up to 250 volts, covering outputs from 1·24-7·2 oz. in., continuous or intermittent ratings. To assist in choosing the correct type, a selection curve is available giving intermittent rating times.

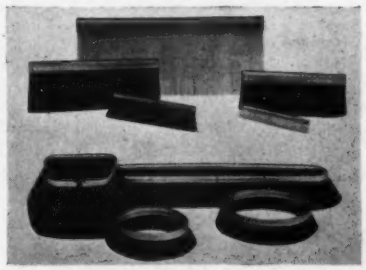
Dimensions have been standardised as much as possible throughout the range, only four different core lengths being employed, and two sizes of shaft diameters are available as standard. Gearboxes are also available as a standard fitment where required.

P type motors can be applied to fan heaters, projectors, vending and office machines, domestic equipment and similar apparatus. Limit Engineering Group Ltd., 64 Essex Road, London, N.1.

EMD 4305 for further information

Brush Strip

Kez-strip is metal-backed brush supplied in lengths for application to a large variety of uses. The strip can be formed to special shapes (a few of which are shown) for incorporation in machines of



many descriptions. These shapes include spirals and helices. Large brushes can be built up from removable and renewable sections. The Kleen-E-Ze Brush Co. Ltd., Hanham, Bristol.

EMD 4306 for further information

Solenoid Valve for Flow Systems

To be used in flow systems as an on/off control where the maximum flow rate is 525 ml./min. at 60 cm. head of water, the Grundy solenoid valve is a cylindrical glass valve with a metal-cored glass plunger, actuated by a concentric solenoid from a mains control unit. The glass valve has an overall length of 110 mm. and is cylindrical, being 70 mm. long by 16 mm. in dia., with riffled extensions to accommodate 5-mm.-dia. tubing.

The cylinder contains a metal-cored glass plunger with a ground glass plug at one end which sits into the ground surface at the constricted outlet of the valve. The glass valve is mounted through the solenoid, which is housed in a metal casting 90 mm. in dia. and 57 mm. long, with an integral bosshead to accommodate rods of up to ¼ in. dia. The control unit is a step-down mains transformer tapped at 12 V., with three circuits for controlling simultaneously (up to) three solenoids for operation on 200/250 V. at 50 c/s a.c. Griffin & George Ltd., Ealing Road, Alperton, Middlesex.

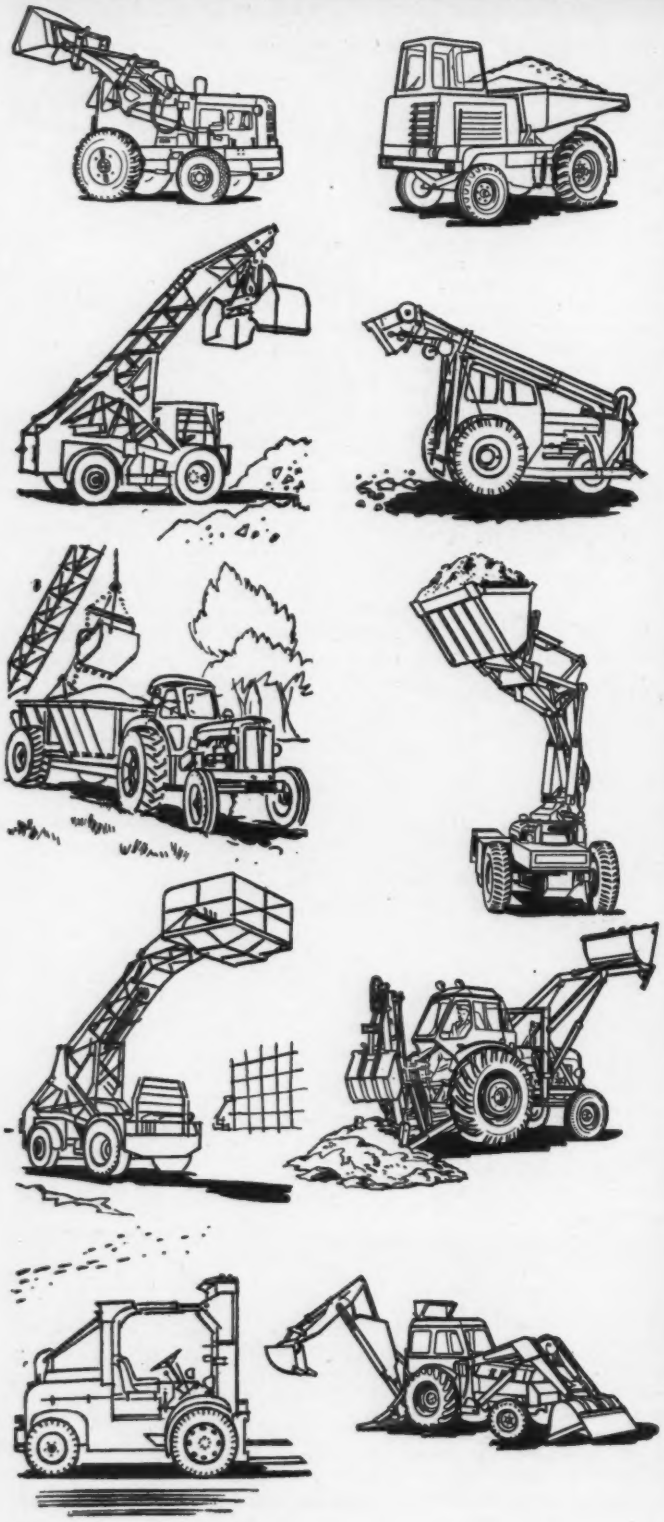
EMD 4307 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

EMD 4218 for further information

EXPERIENCED OPERATORS INSIST ON



FORDSON POWER

Men who have kept to the tightest schedules in the toughest conditions; men who have manned machines working round the clock, seven days a week; these are the men who know from experience that for proved reliability Fordson Power is unequalled. Add to reliability all the other Fordson advantages of high output, low costs, unrivalled service and spare parts organisation, and almost unlimited choice of build-ups in the 30-40 and 40-50 b.h.p. classes. That's why more Fordson power units than any other are used in industrial equipment. Write for detailed specifications.

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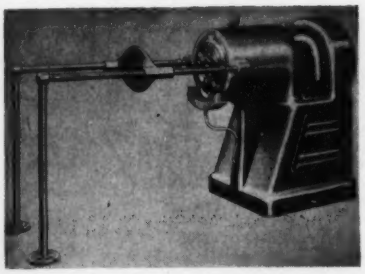
Tube Tapering Machine

The Iariston tube tapering machine will taper tubes up to 2 in. in diameter; die lengths obtainable are 12, 16, 18 and 22 in., which makes it a particularly suitable machine for the metal furniture, motor cycle and bicycle manufacturing trades, as well as others engaged in tube manipulating. The tube to be tapered is introduced into the machine along the axis of the rotating spindle, either by hand or by a tube-pushing device. The tube then undergoes a hammering action by a pair of moving dies placed symmetrically to the axis of the spindle.



Additional equipment obtainable with the Iariston includes special dies for doming the ends of tubes, and an attachment for producing tapers on bent tubes. Power is obtained from a 10-h.p. motor through V belts and flywheel; lubrication is taken care of by a pump which forces lubricant from the sump in the base of the machine on to the dies and the tubes being tapered. Addison Tool Co. Ltd., Addison House, 28 Marshalsea Road, London, S.E.1.

EMD 4308 for further information

Leadholders and Sharpeners

A new range of leadholders of special interest to the technical draughtsman has been introduced. Longitudinal grooves inside the chuck prevent the lead from turning. This feature, which is patented, ensures that the lead is securely held when being sharpened. A special sharpener, designed specially for use with the leadholder, is also supplied. The leadholders are finished in black, but for identification purposes they are fitted with coloured rings and coloured press buttons in twenty-six different colours. Lawtons of Liverpool Ltd., Vauxhall Road, Liverpool, 3.

EMD 4309 for further information

Dry Duplication

Said to be the only dry process duplicator in the world, the Merlin reproduces copies by means of a chemical reaction in the sensitised copy paper used. It needs no stencils, ink, spirit or liquid of any kind, and is claimed to give up to 100 perfect copies. Ellams Duplicator Co. Ltd., 5 Dean Street, London, W.1.

EMD 4310 for further information

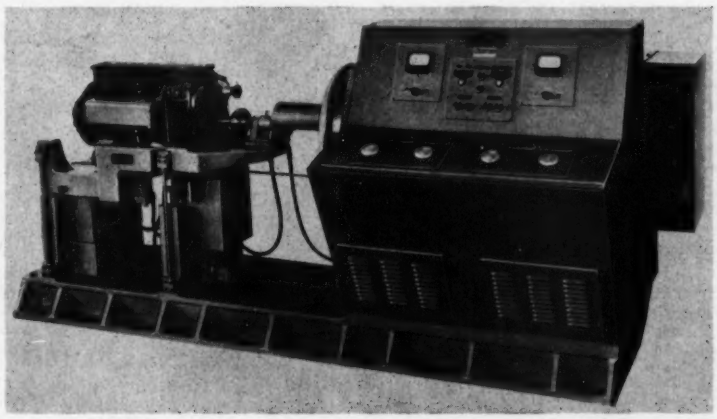
Balancing Machine

Compensating weights of known value are used to determine unbalance in the Compensator balancing machine, which incorporates a pair of synchro motors placed in each of the two planes of correction, thus making it possible to introduce a force which is equal and opposite to the unbalance in an engine (the illustration shows an automobile engine being balanced). Calibration is said to be eliminated. Each pair of synchro motors has two control knobs. The left-hand control (angle) turns the two synchro motor rotors in unison, while the other control (amount) turns them in phase opposition. When they are turned in unison, the angular position of the unbalance is located, and when they are turned in opposition, the amount of compensating unbalance is determined.

In use, an engine is mounted in the balancing machine on a vibratory frame, which moves under the action of the unbalance forces in the engine. This movement is detected by electrical pick-ups, and is shown on a corresponding electrical meter on the upper part of the console.

A simplified compensating - type balancing machine has also been designed for use in the smaller engine rebuild shops, where there are no production runs and each job varies. The component to be tested is mounted on a special stand with adjustable cross brackets, and may be driven by an external motor or under its own power. Edward G. Herbert Ltd., Atlas Works, Levenshulme, Manchester, 19.

EMD 4311 for further information



New Publications and Technical Literature

Acheson Colloids Ltd.: 12-page booklet of data on the standard Acheson dispersions. P.O. Box 12, Prince Rock, Plymouth.

EMD 5312

Engelhard Industries Ltd.: First issue of the *Engelhard Industries Technical Bulletin* (48 pages), which is a quarterly survey of contributions of scientific, technical and practical interest resulting from developments in the fields served by the company. Baker Platinum Division, 52 High Holborn, London, W.C.1.

EMD 5313

E.M.I. Electronics Ltd.: 24-page booklet, in colour, describing six typical uses of the Emidec 1100 all-transistor data processing system. Computer Division, Hayes, Middlesex.

EMD 5314

John Holroyd & Co. Ltd.: "Holfos Bronze", a 60-page catalogue describing the company's current manufacturing facilities, and giving details of the more important materials produced. P.O. Box 24, Holfos Works, Rochdale, England.

EMD 5315

Croda Ltd.: Four technical data sheets: "Croda strippable plastics coatings"; "Cropeel plastics coating"; "Proil oily film rust preventive"; and "Tylac rust-prevention varnish". Cowick Hall, Snaith, Goole, Yorkshire.

EMD 5316

Londex Ltd.: 16-page illustrated catalogue containing data on the Londex vacuum and pressure switches. Anerley Works, 207 Anerley Road, London, S.E.20.

EMD 5317

Linford Engineering Co. Ltd.: 7-page brochure describing the company's rams, pumps and other hydraulic equipment. Baker Street, Birmingham, 11.

EMD 5318

Chesterfield Tube Co. Ltd.: Report on three years' research on the fabrication of beryllium tubes and sections (illustrated 15-page brochure). Chesterfield, Derbyshire.

EMD 5319

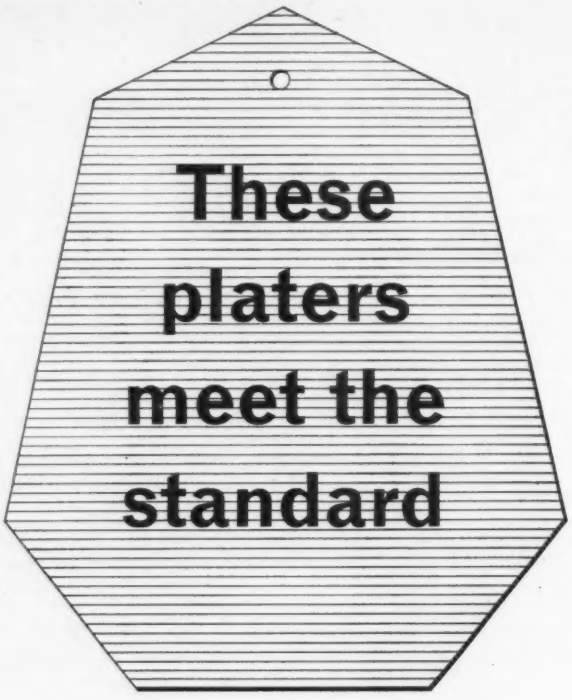
Simmonds Aerocessories Ltd.: Well-illustrated 26-page brochure describing the Fram industrial filters and strainers. Treforest, Glamorgan.

EMD 5320

Shell Chemical Co. Ltd.: 23-page brochure on laminating with Epikote resins. 170 Piccadilly, London, W.1.

EMD 5321

EMD 4219 for further information



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TGA P4

News of Industry

A Solid State Physics Division has been formed at the **Atomic Energy Research Establishment**, Harwell. Its initial term of reference will be to carry out basic research leading to greater knowledge and understanding of the structure and behaviour of solids.

The formation of this new Division reflects the importance which the Authority attaches to a better understanding of the structure and properties of solids. The nuclear reactors at Harwell, and particularly the research reactor BEPO, and the materials testing reactors DIDO and PLUTO, play a very important part in studies of the properties of materials. The basic and applied studies include the effects of nuclear radiation on materials important to reactor technology, and more research on the behaviour of solids in general.

Rubery Owen & Co. Ltd. have recently entered the reinforced plastics field, and their products include valve caps, welding cabinet tops, sink units, baths, office furniture and wheel-barrow hoppers. One of the major advantages of their Ro-Plas process is the speedy production of tools at low cost, which should receive favourable consideration from potential customers. Other new products recently introduced include a new range of multi-unit metal shelving, and dove-tailed floor flags laid in concrete which constitute a strong, durable, non-skid flooring ideal for many industrial applications.

Concrete is the most widely used bridging material in Britain, and because of economic advantages of a standardised form of bridge construction, the **Prestressed Concrete Development Group** has co-operated with the Ministry of Transport in preparing a design for a standard type of bridge construction using precast, prestressed concrete beams. Within the range of spans from 25-55 ft., two types of beam are recommended for consideration; the beams are designed to withstand the load of the in situ concrete and construction traffic, and to act monolithically with the concrete to carry live loads. A minimum thickness of 3 in. of concrete is placed over the beams; the precise thickness is determined by the design requirements.

An ingenious all-British design by **Sovex Ltd.**, of Erith, offers a completely automatic system of loading and off-loading baggage and stores from a quay to the various parts of a ship, thus reducing the expensive turn-around time in port. This system, which has been applied to the new P. & O. passenger liner *Oriana*, makes the ship completely independent of shore installations for the handling of baggage and stores for the 3,100 passengers and crew, and supplants traditional methods of handling.

Bristol Siddeley have announced that, by agreement with Svenska Rotor Maskiner, of Stockholm, they will manufacture at their Power Division, in Coventry, a range of SRM hydraulic torque converters. These converters are used to transmit power at increased torque and reduced r.p.m. in applications such as motor vehicle and railcar transmissions, the ratio being usually variable up to direct drive. The dual rotation feature of the SRM converter combines a high efficiency with unusually high torque ratios, 9:1 being achieved at stall conditions.

A fleet of fuel-carrying tyres are in field operations with the U.S. Army. These rolling liquid transporters, produced by the **Goodyear Tire & Rubber Co.**, each carry 500 gallons. Two units in tandem, carrying a total of 2,000 gallons, have been successfully towed behind a personnel carrier. The tyre tanks were developed

to the specifications of the Army's Transportation Research Command, and they can be towed by any type of vehicle, their unusual construction giving them low ground-bearing pressure on a wide contact area, and allowing them to function in the most difficult off-the-road conditions.

Vacuum techniques are being applied to many different and highly automated manufacturing processes, and in order to ensure the thorough integration of these two aspects a new joint company, **Leybold-Elliott Ltd.**, has been formed by Elliott Bros. (London) Ltd. (a member of the Elliott Automation Group) and Leybold's of Cologne. The range of vacuum components available, many of which are already in production in this country, include rotary-diffusion pumps, gauges and mass spectrometers. Complete plants for drying plastics, freeze drying, degassing-drying, impregnating, vacuum coating and leak detection can be supplied.

Bristol Aerojet Ltd. and **Permali Ltd.** are to collaborate in the manufacture and selling of specialised tubular structures of helically wound glass-fibre rovings bonded with synthetic resin. Manufacture will be undertaken by Bristol Aerojet, selling by Permali, while design and development will be a joint responsibility.

The Distillers Co. Ltd. recently announced the formation of a Development Division in their Industrial Group. The main responsibilities of this Division will be the direction and co-ordination of the company's research, forward planning and licensing activities, particularly in the fields of chemicals and plastics.

Aluminum Company of America and **Aeroprojects Inc.** have announced the acquisition by Alcoa of foreign rights to sell and also license the manufacture of Sonobond ultrasonic metals-joining equipment. Ultrasonic joining tools manufactured by **Sonobond Division**, a subsidiary of **Aeroprojects Inc.**, are used to weld, braze and solder metals by the application of ultra-high-frequency vibrations, the equipment being known by the trade names of Sonoweld, Sonobraze and Sonosolder. Ultrasonic joining is utilised in the electronic, aircraft, electrical, packaging, aluminium fabrication and atomic energy industries in the U.S.A. This technique produces a strong, sound, metallurgical bond in a wide variety of metals without arc, fusion or spark, and with virtually no deformation. In addition to spot-type and continuous seam welds, Sonoweld machines may be used to combine these weld forms to produce ring and area welds. In the majority of operations, special surface preparation is not necessary, and materials joined do not have to be of the same thickness, it being possible to unite the thinnest foil with the heaviest plate.

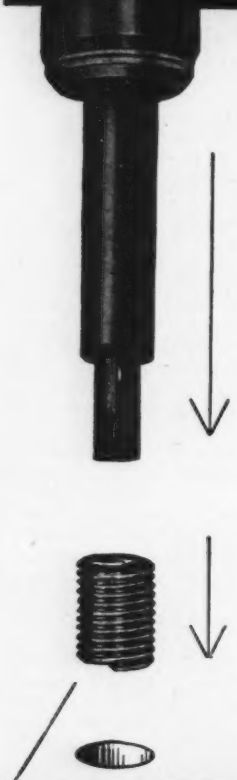
Special-purpose machinery inevitably arouses the interest of designers, particularly when a company in a specific industry designs or modifies machinery to achieve an improvement in quality and quantity. Such a company is **Spicers Ltd.**; many of the machines used in their stationery factory have been designed and developed by the Director of Factories of the Spicers Group, Mr. B. E. M. Monck. Improvement in output and human relations with the operators are exemplified by the successful integration of managerial and technical skill. A typical modification based on experience has enabled a machine to produce envelopes at the rate of 400 per min, the highest speed achieved in this country for the particular type of envelope.

MEETINGS

The third **International Metal Spraying Conference** will be held in Madrid, from October 2-6, 1961.

A three-day International Conference on "The Metallurgy of Beryllium" is to be held by **The Institute of Metals** in London on October 16, 17 and 18, 1961. It is intended to cover the whole field of the metallurgy of beryllium, with the exception of the extraction process, and papers are invited.

. . . every time this happens someone saves ½d a hole



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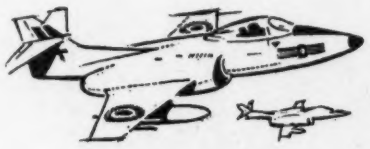

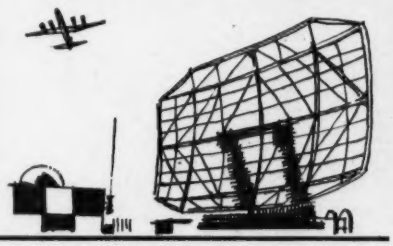

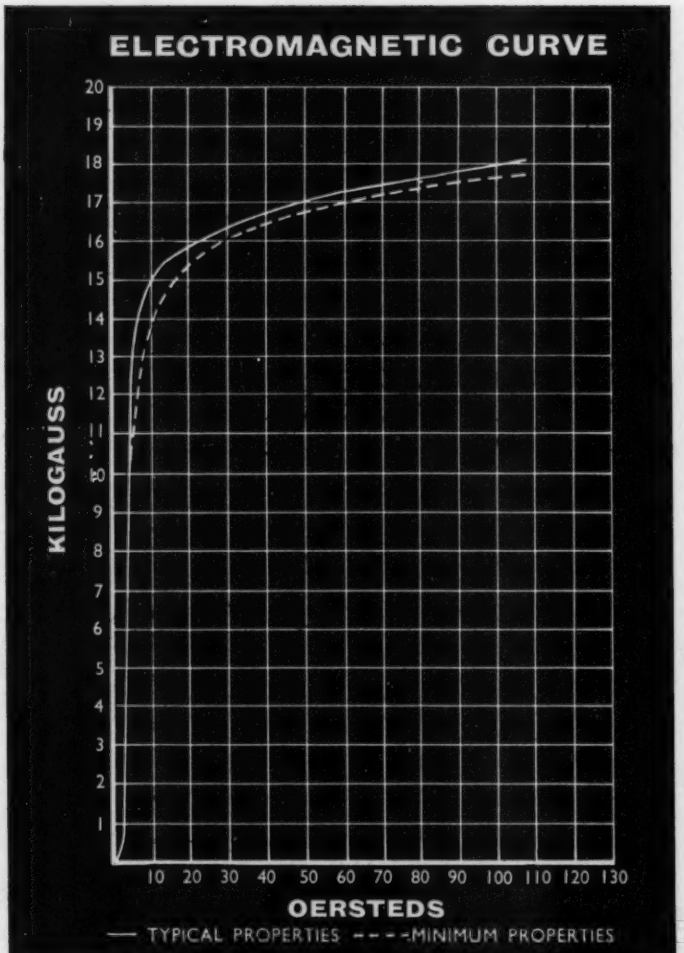

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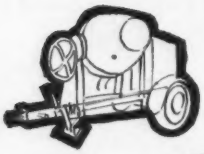

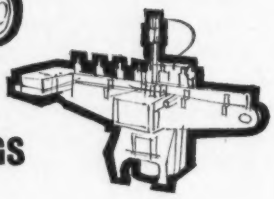

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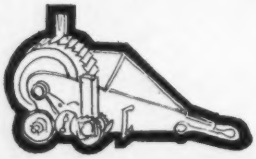

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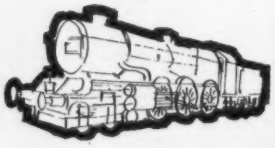

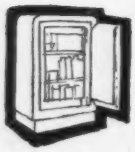

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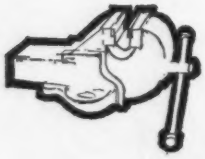

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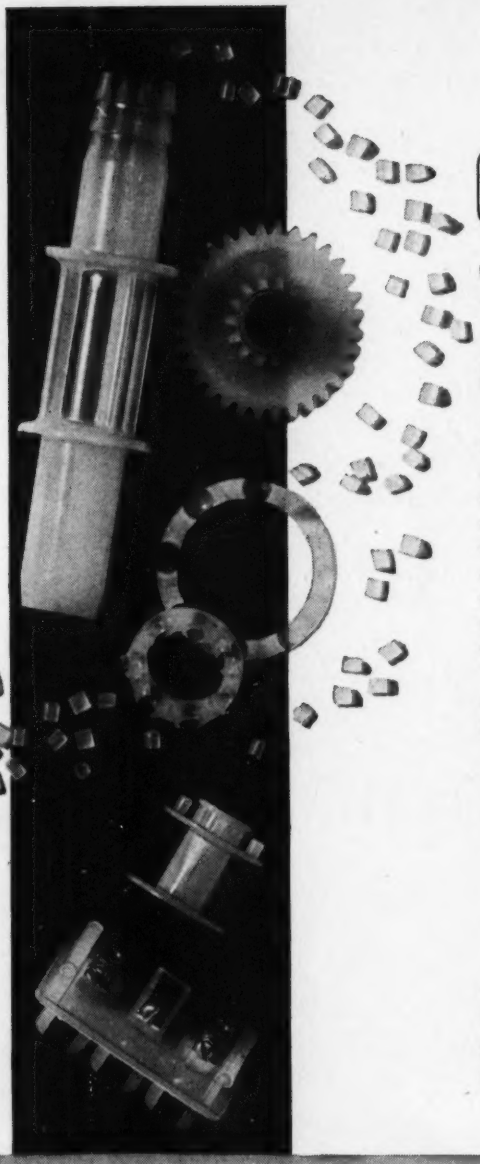

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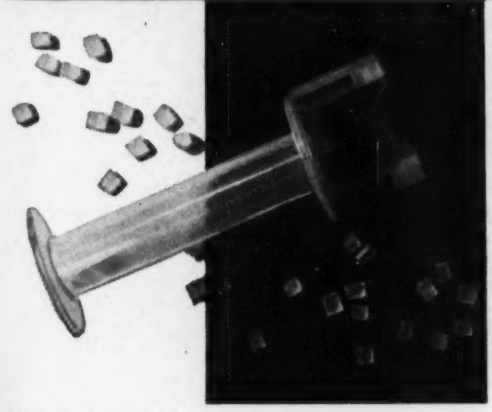

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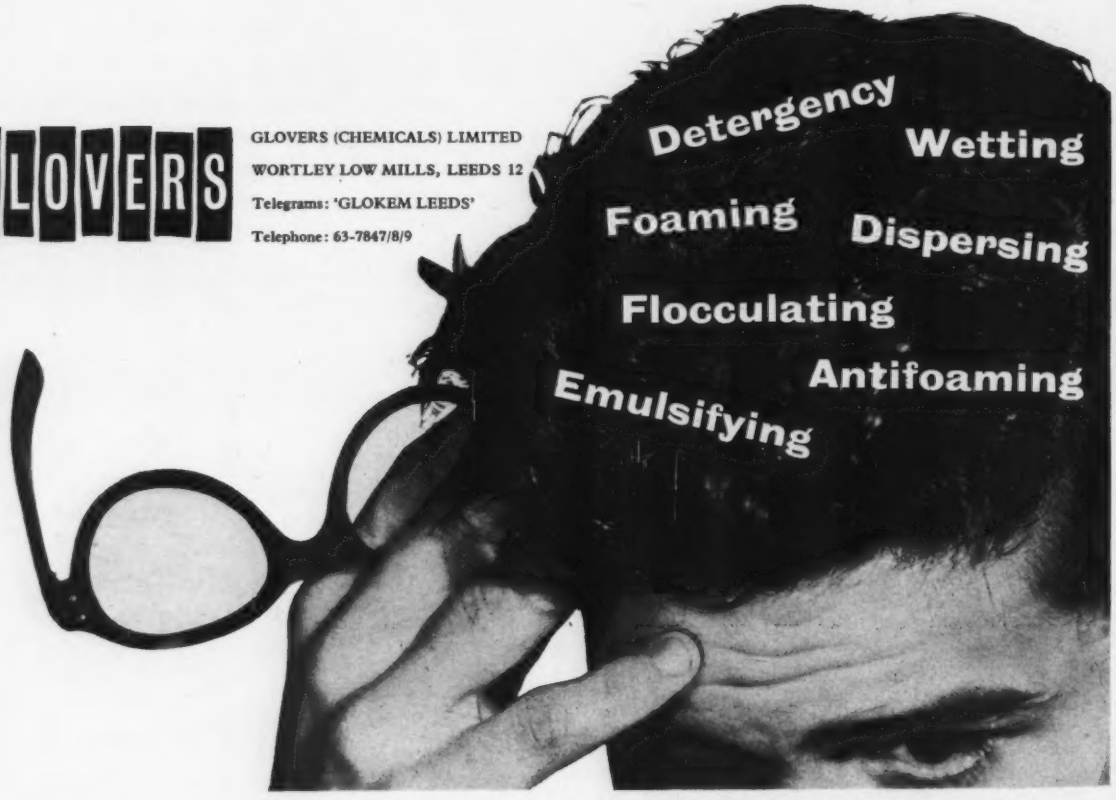

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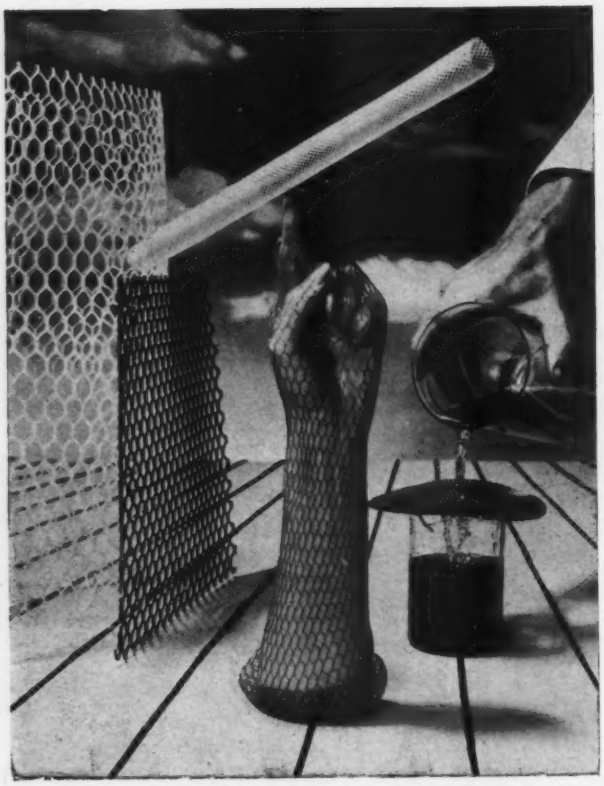

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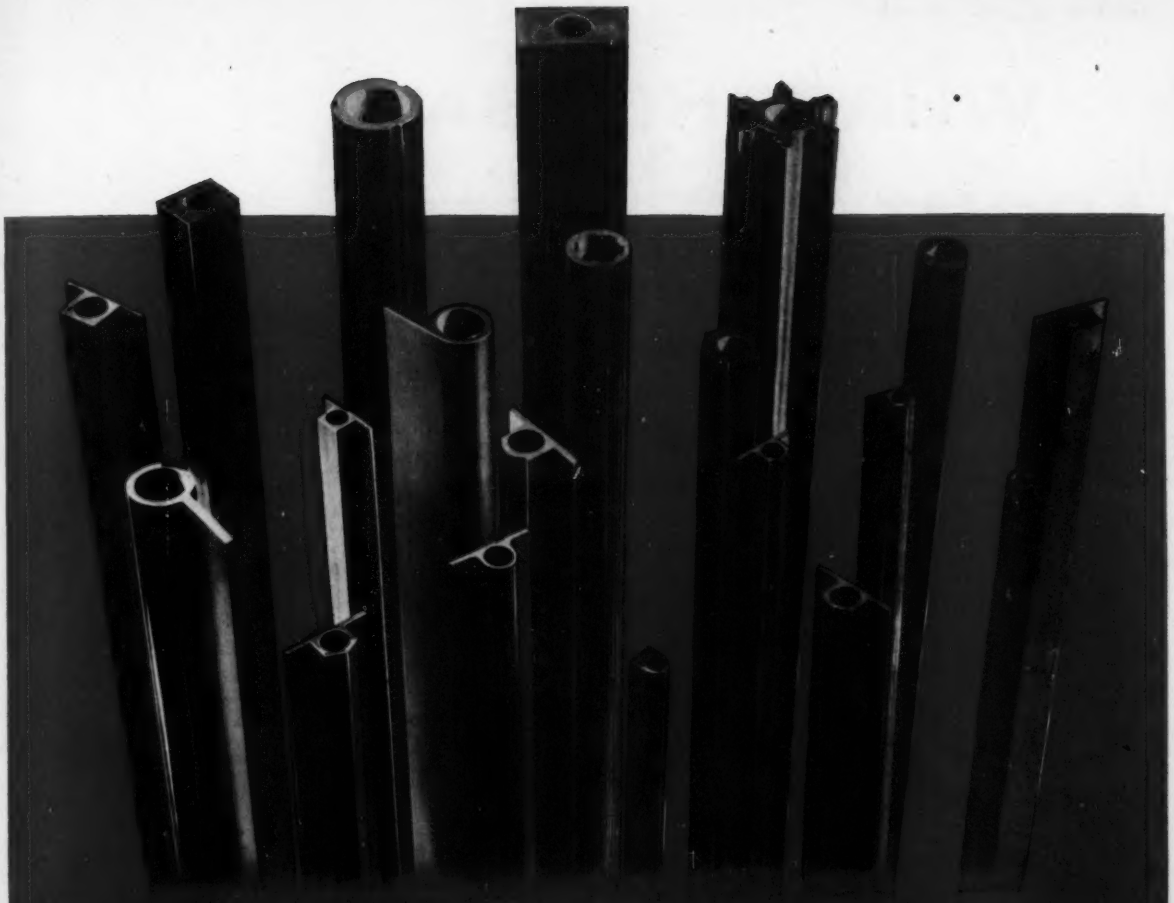

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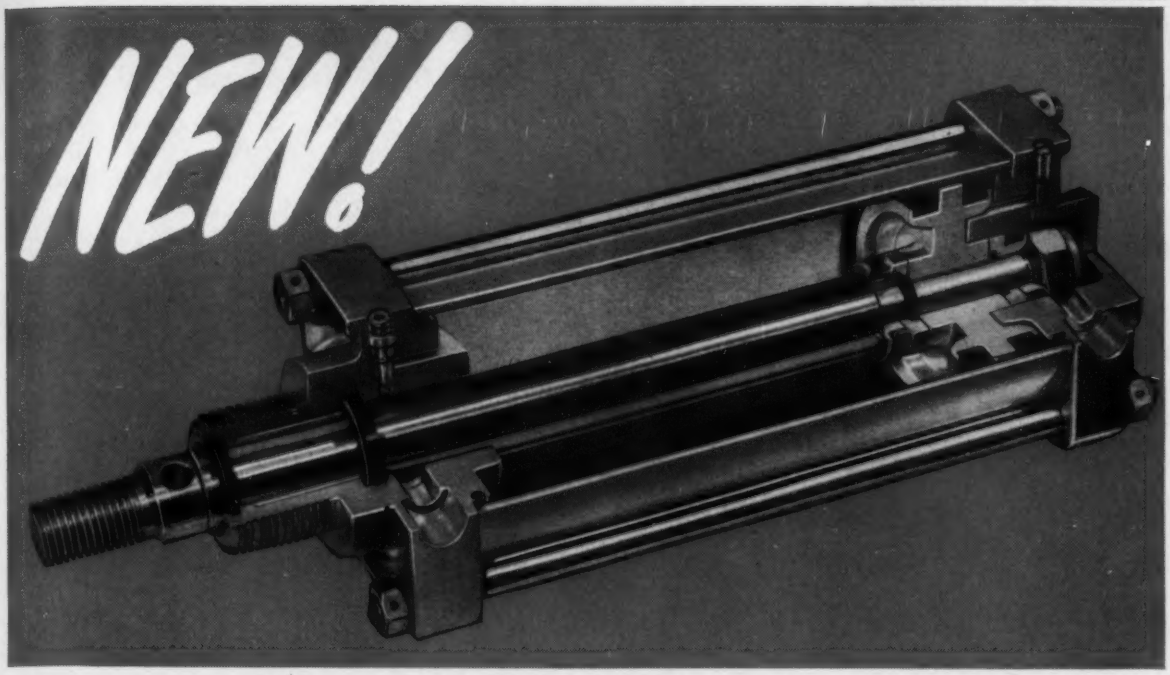

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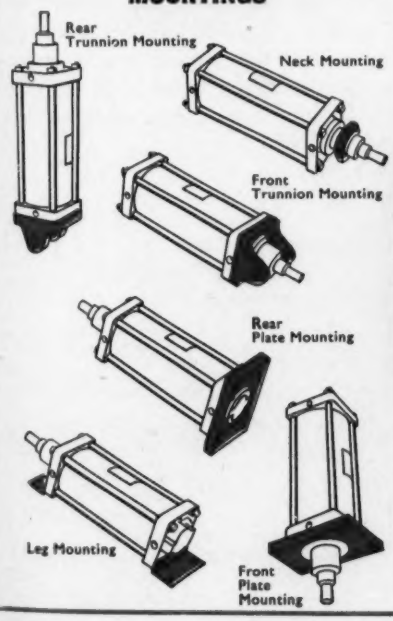

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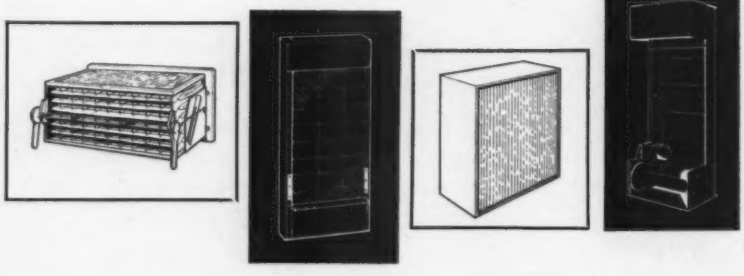

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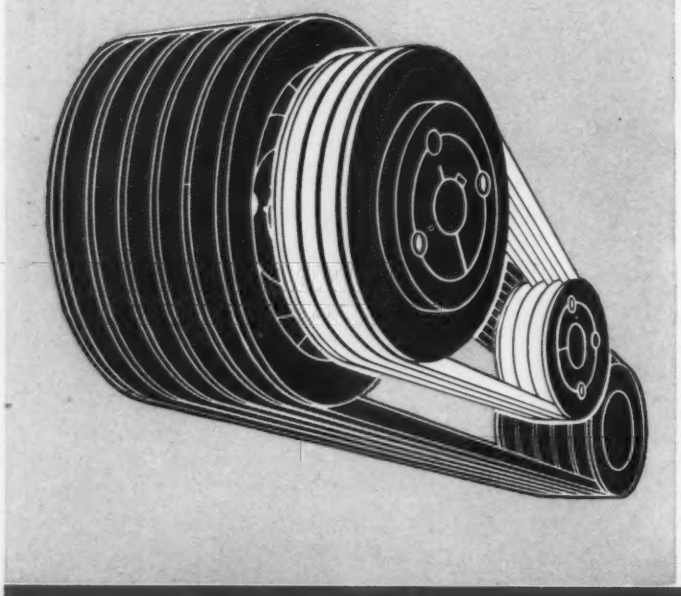

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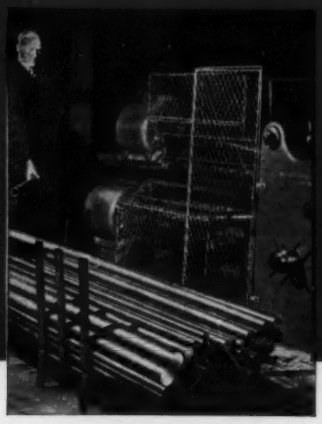

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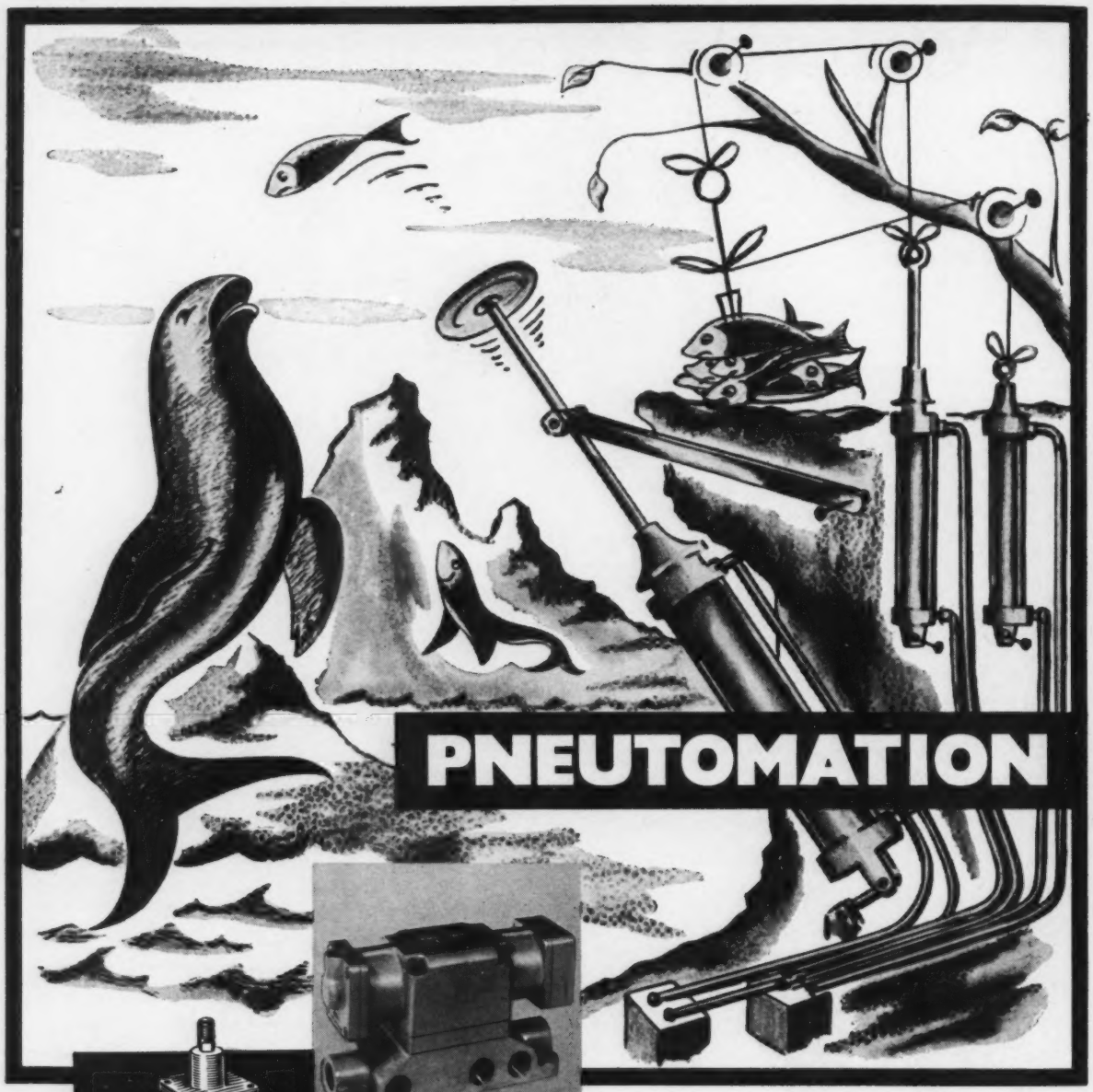

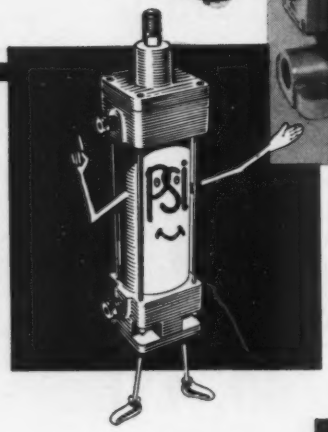

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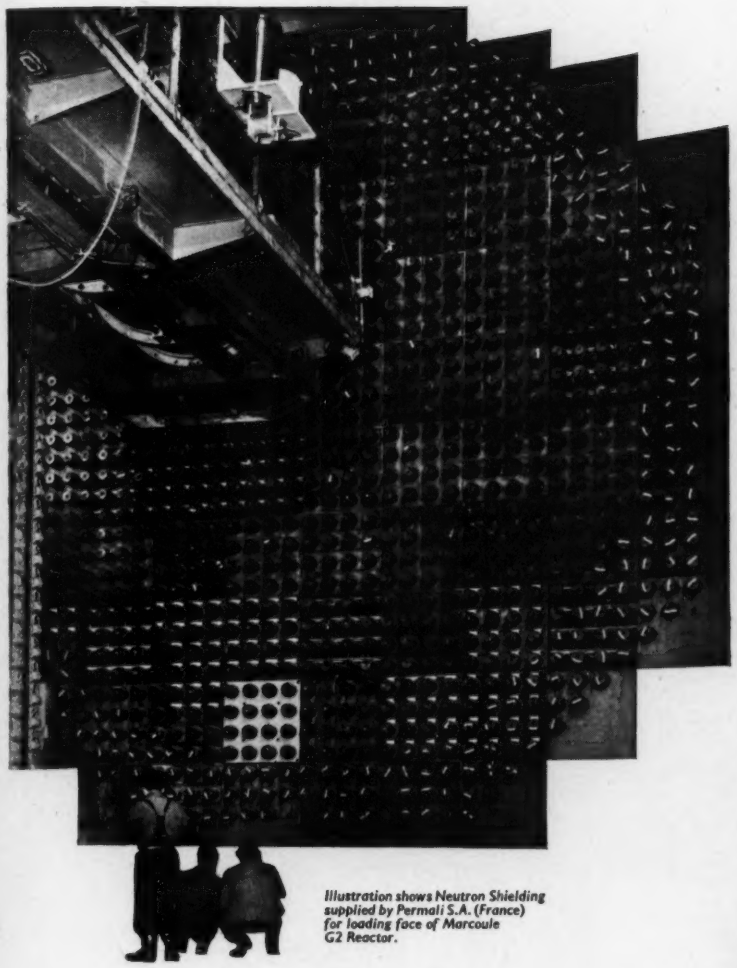

Illustration shows Neutron Shielding supplied by Permali S.A. (France) for loading face of Marcoule G2 Reactor.

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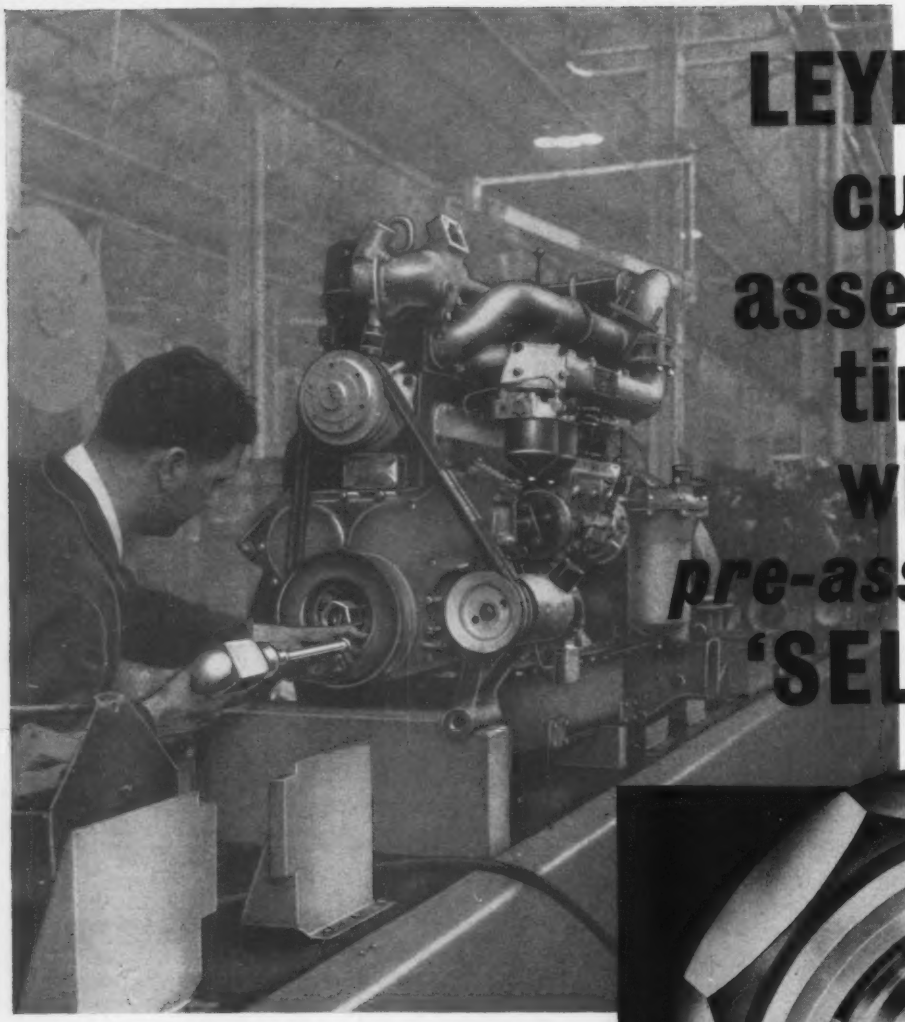

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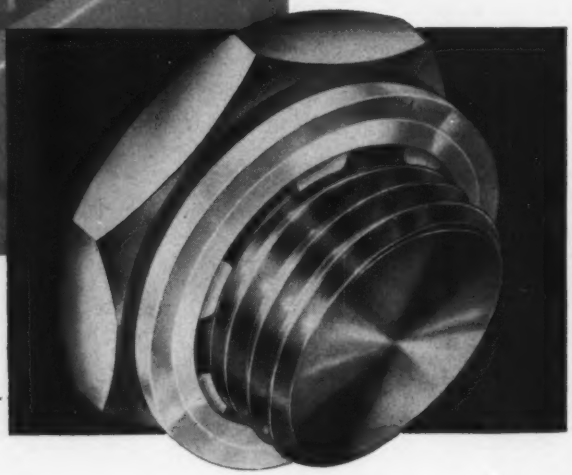

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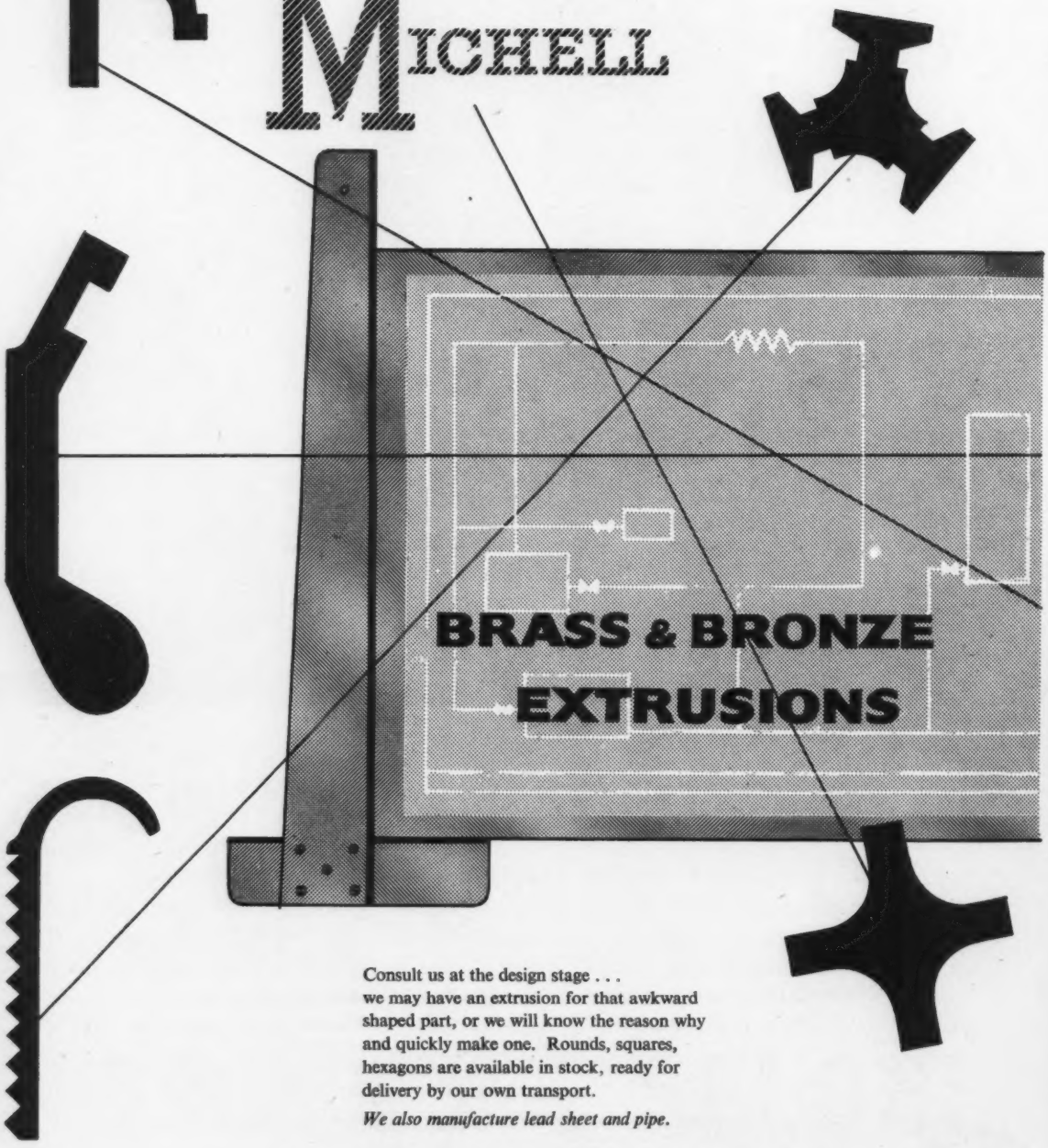

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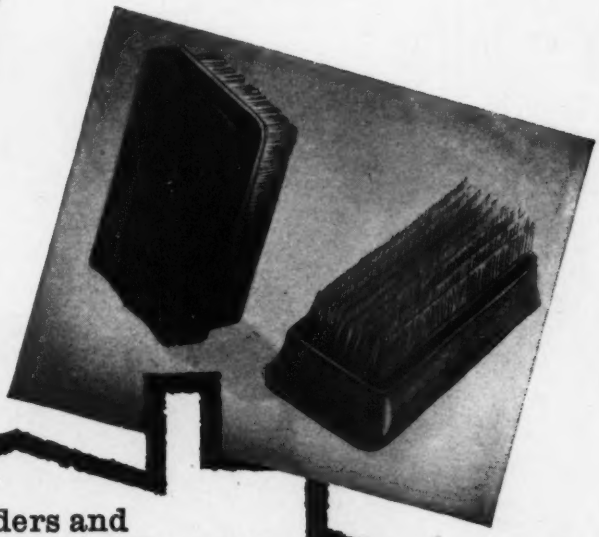

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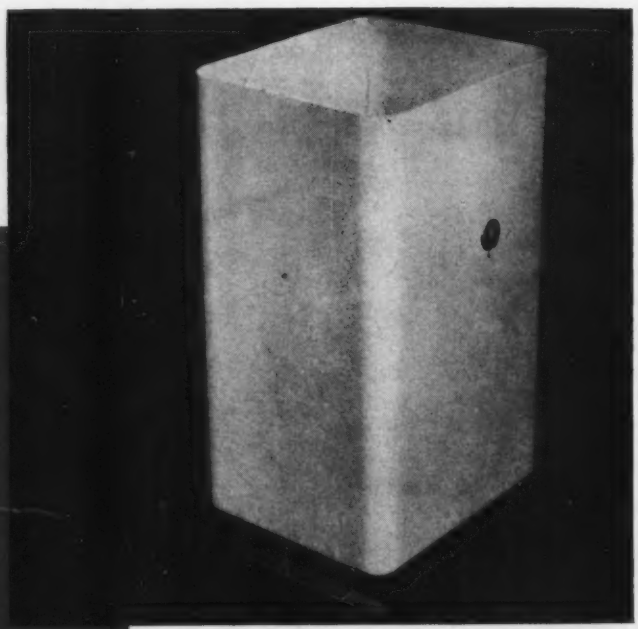

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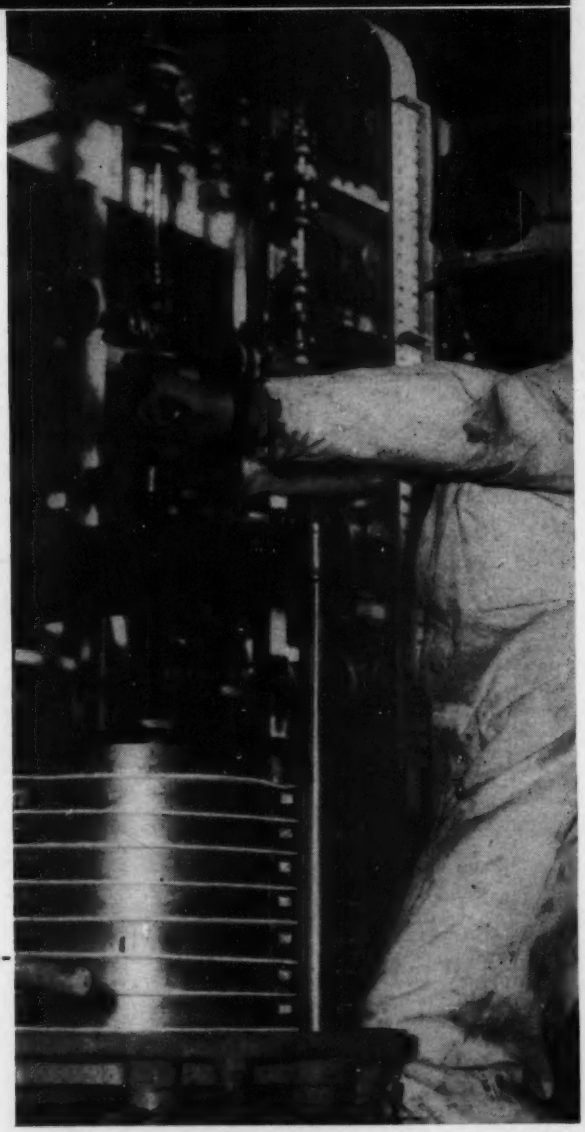

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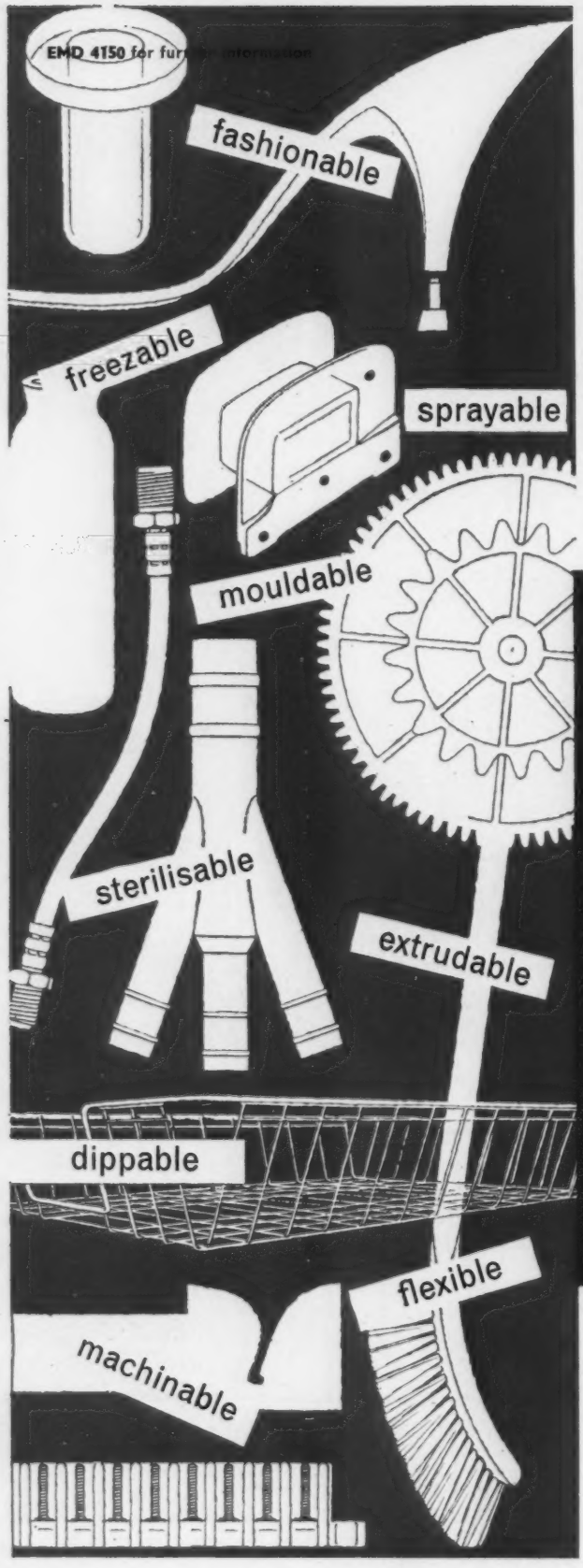

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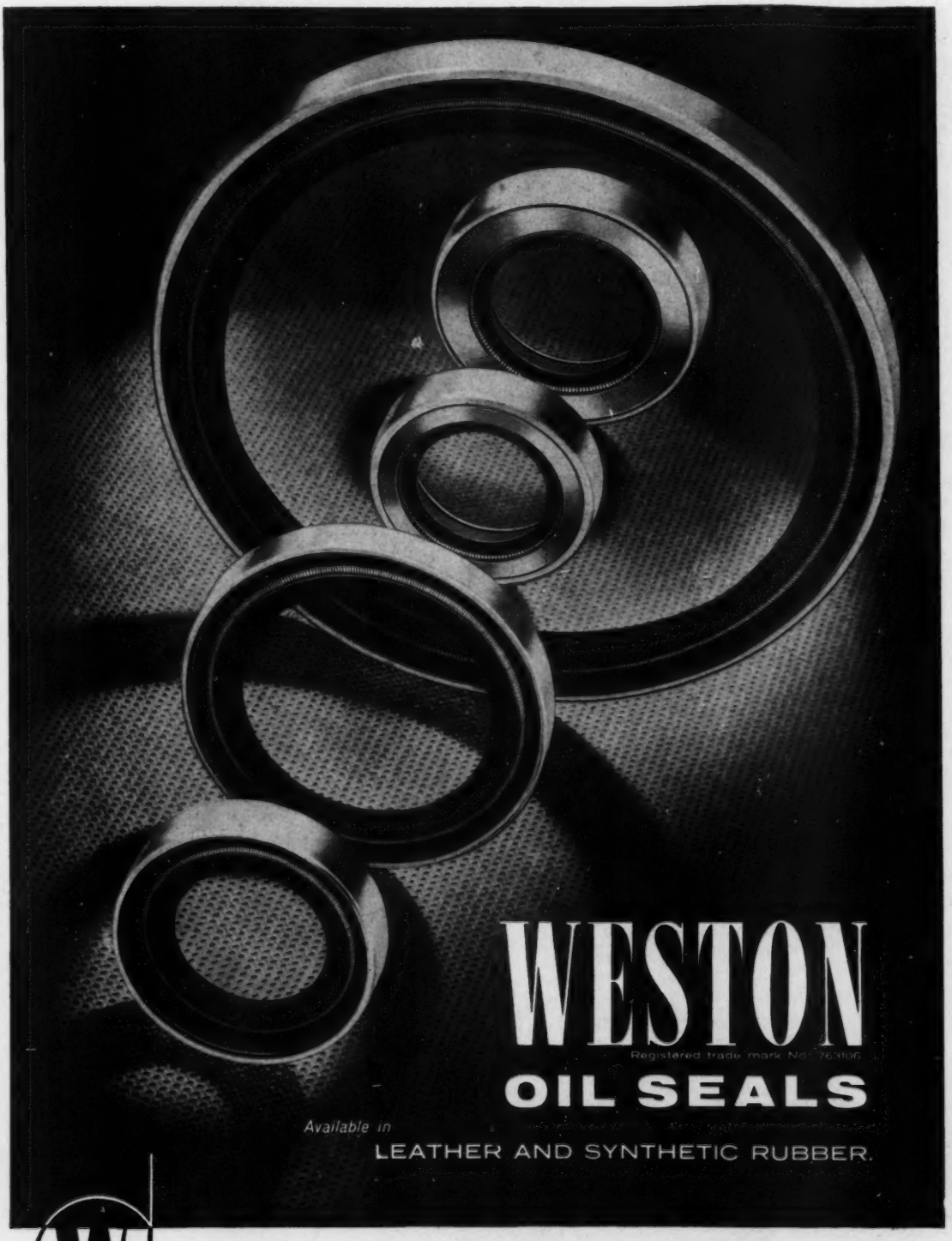

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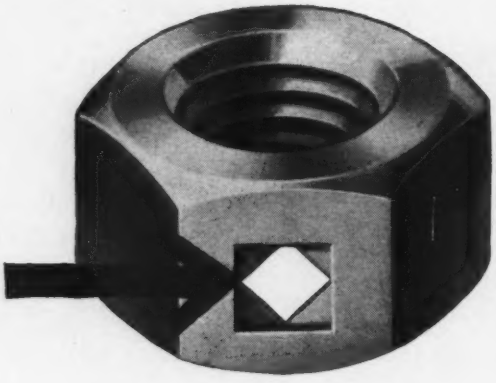

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Tecalemit, pioneers of extruded nylon tubing, owe their present supremacy in this sphere to the most exacting research, testing and development in co-operation with the producers of the raw material. Tecalemit have now achieved marvellous limits of precision in extruded nylon tubing—limits unequalled and indeed unthought of previously—an exclusive technical triumph.

Flexible and rigid Tecalemit nylon tubing now outperforms metal, other plastics and rubber for industrial and automotive oil and fuel lines. Tecalemit Tubing is fitted as standard by such great names as Aston-Martin, Austin, Ford, International Harvester, Jaguar, Massey-Ferguson, Rover and many large industrial users including, of course, Tecalemit industrial lubrication installations.

Tubes of precise inside diameter of ¼" and less have proved under test to be unharmed by

1,100 vibrations per minute at 250°F and 45 p.s.i. for 700 hours

immersion in Derv at 212°F for 200 hours

air temperatures of —78°C

tensile strains of 100 lb (after being dry-air aged at 212°F)

And they save up to 50% in initial cost!

Tecalemit Nylon Tubing almost halves fitting times; is free of internal abrasive scale; resists shock, even below -70°C; resists most solvents, corrosion and fungal attack; is unaffected even by strong ultra-violet light, and form-stable over a wide temperature range.

For full particulars write to:

TECALEMIT LTD. (SALES EM)

PLYMOUTH · DEVON

NEW! **TECALEMIT HIGH PRESSURE NYLON HOSE**

Following in the great tradition of Nylon Tubing, Tecalemit present a new High Pressure Nylon Hose. More durable, flexible, lighter, stronger and more stable than any other hose on the market. And highly competitive in price! Ask for details when enquiring about Tecalemit Nylon Tubing.

T695

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Flash Welding

by REYNOLDS

MATERIALS range from Mild and Stainless Steels to heat resisting "Nimonic" Alloys.

WELDING CAPACITY of up to 15 sq. ins. in Mild Steel, 6½" dia. and 8 ins. cross sectional area of Mild Steel Tubes.

WELD QUALITY of complete uniformity and accurate tolerances minimises machining.

MODERN MACHINES of up to 60 tons upset capacity.

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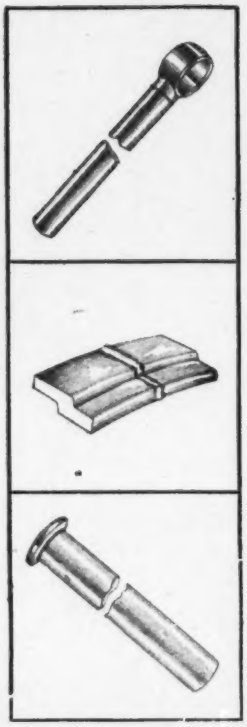
WELDING FACILITIES are supported by comprehensive manipulation and heat treatment plant.



Ask REYNOLDS Technical Staff to Advise on the application of **Flash Welding** to YOUR products.

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We are manufacturers of Power Transmission Equipment and offer the following range of products:
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Industrial Power-Take-offs, S.A.E. Housings
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W·R·Anderton & CO LTD *Clutch Manufacturers*

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POSITIVE INFINITELY VARIABLE
FRACTIONAL *hp* GEARBOXES

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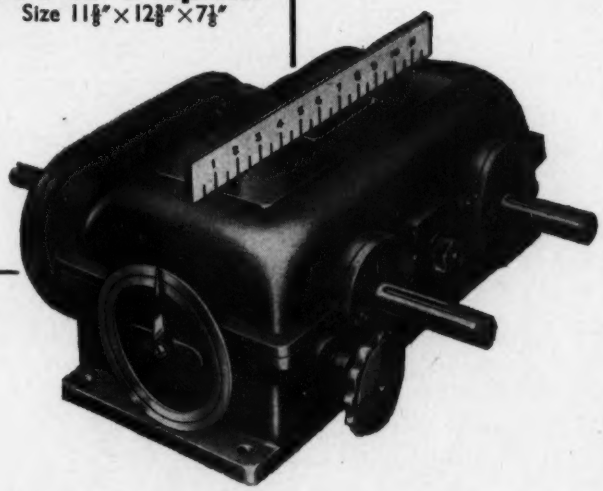
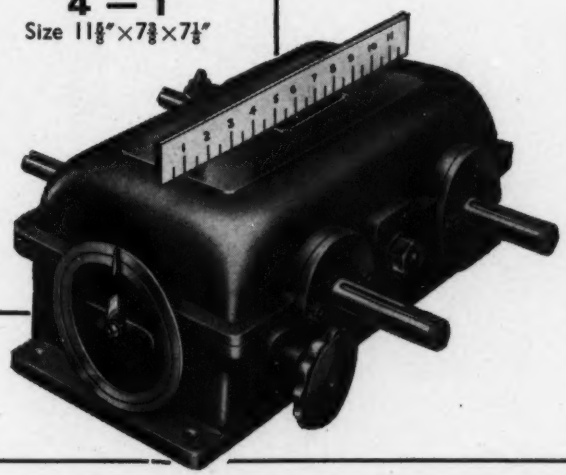
SPEED RANGE
700 to 0 r.p.m.
Size 11⅛" × 12⅜" × 7⅛"



The twelve inch rule indicates relative dimensions.

TYPE OA
SPEED RANGE
4 — 1
Size 11⅛" × 7⅜ × 7⅛"



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NOW YOU CAN SPECIFY LIGHT WALL BUTT-WELD PIPE FITTINGS

In answer to a growing demand, Truflo light wall pipe elbows and fittings are being produced by Wilmot Breeden—and are available throughout the U.K.

For the first time construction engineers in Britain are now assured of a regular supply of fittings. And because of mass-production prices are favourable.

Truflo light wall fittings are ideal for piping systems in chemical, petro-chemical, nuclear and process plants—where stainless steel and nickel alloys are specified.

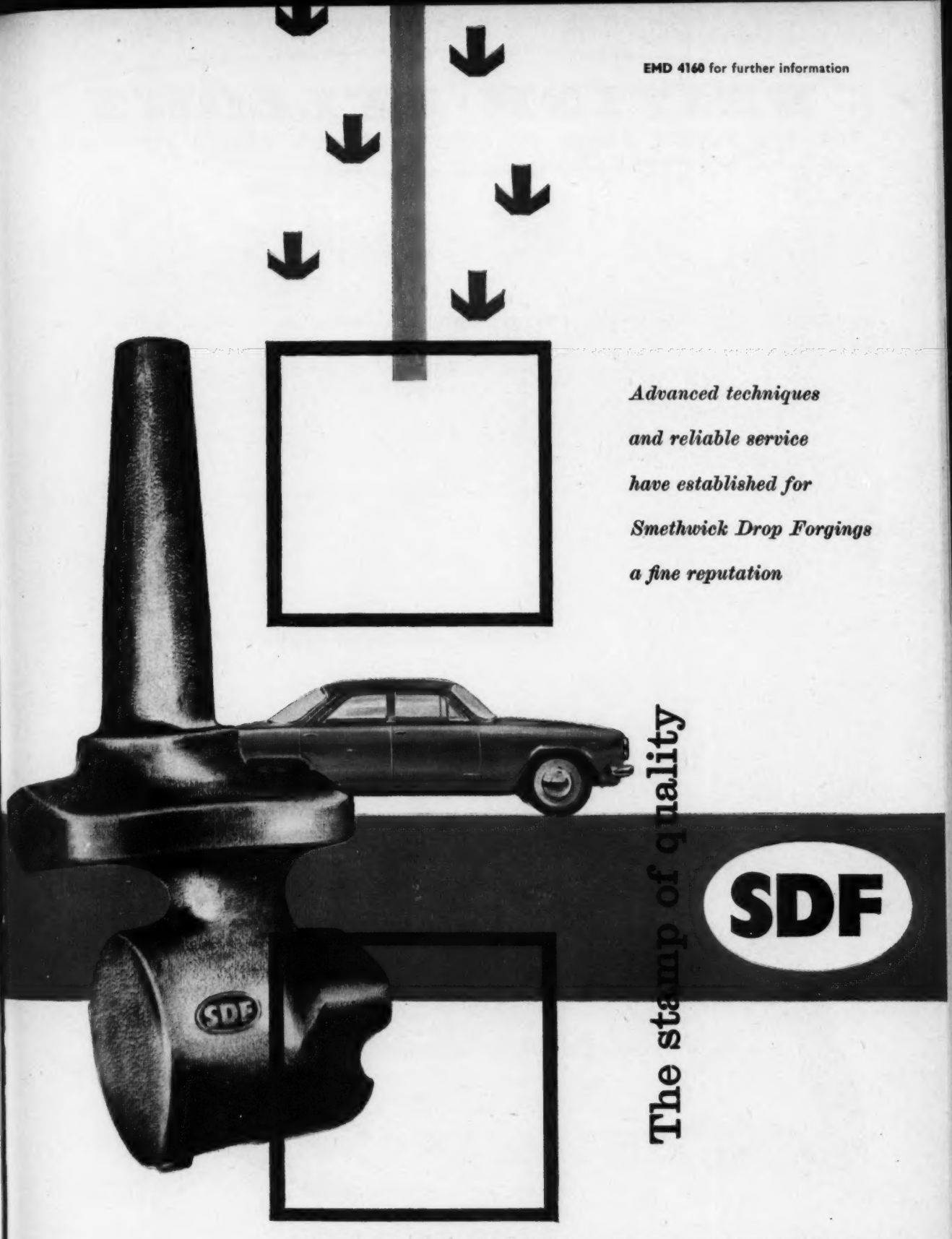
The range of Truflo fittings is made in extra low carbon stainless steel, nickel, Monel*, Inconel*, and Corronel 210* in various scheduled wall thicknesses.

Truflo fittings conform to the dimensional requirements of American standards ASA.B36.19 and MSS.SP-43 for schedule 5s and 10s wall thicknesses and ASA.B16.9 for schedule 40s and greater. British standard BS.1640 also applies, and in all cases materials conform to ASTM.A.312 and A.403 (stainless) and ASTM.B127 and B162 (nickel alloy).
**Registered trade names of Henry Wiggin & Co. Ltd.*

TRUFLO by WILMOT BREEDEN

For detailed catalogue, write to: Sales Manager, Dept. 8
Wilmot Breeden Ltd., Goodman Street, Birmingham, England.
Telephone: Central 8691.

EMD 4160 for further information



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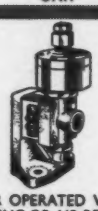
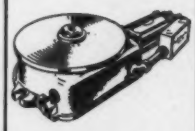
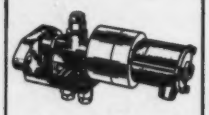


AIR OPERATED VALVE (SPRING OR AIR RETURN)



ROTARY FEED TABLES

EXPLOSION-PROOF ELECTROAIRE VALVE



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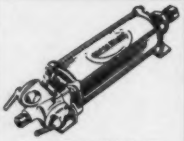

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HYDRAULIC CHECK CYLINDERS WITH SKIP AND STOP CONTROLS DOUBLE ACTING

How to get parts to and from a machine faster . . . to shave seconds off the inter-stroke tool time? Such are the methods man's problems. His answer is British Bellows Air Power Equipment, for work feeding, work holding, tool feeding, etc. For short run or long run, individual or in combination. The British Bellows booklet gives you full facts on the multi-purpose range of units—*proved in production.*

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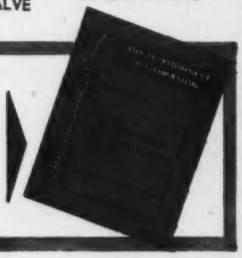

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Klikax retaining rings are used in their millions throughout the world giving continuous proof of their absolute security. They can effect economies amounting to 50-80% in time and labour. The maximum savings can be achieved more easily with the Klikax Stacker and Applicator on all forms of production line assembly using E clips.

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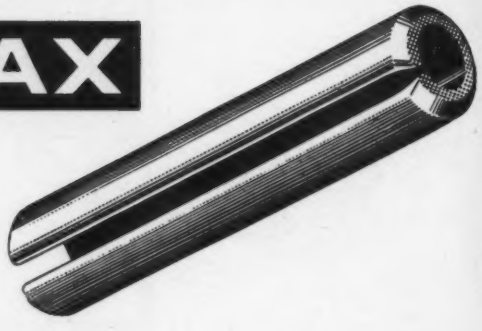

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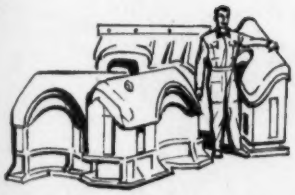
Take a sales curve and relate it to the shape of your new product. Perhaps dies come into it. Dies that are precise though large. Dies with a fine finish. Dies soundly constructed for dependability under the stresses of modern mass production press work. Vickers design them, make them, prove them, give satisfaction with them.



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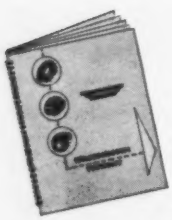
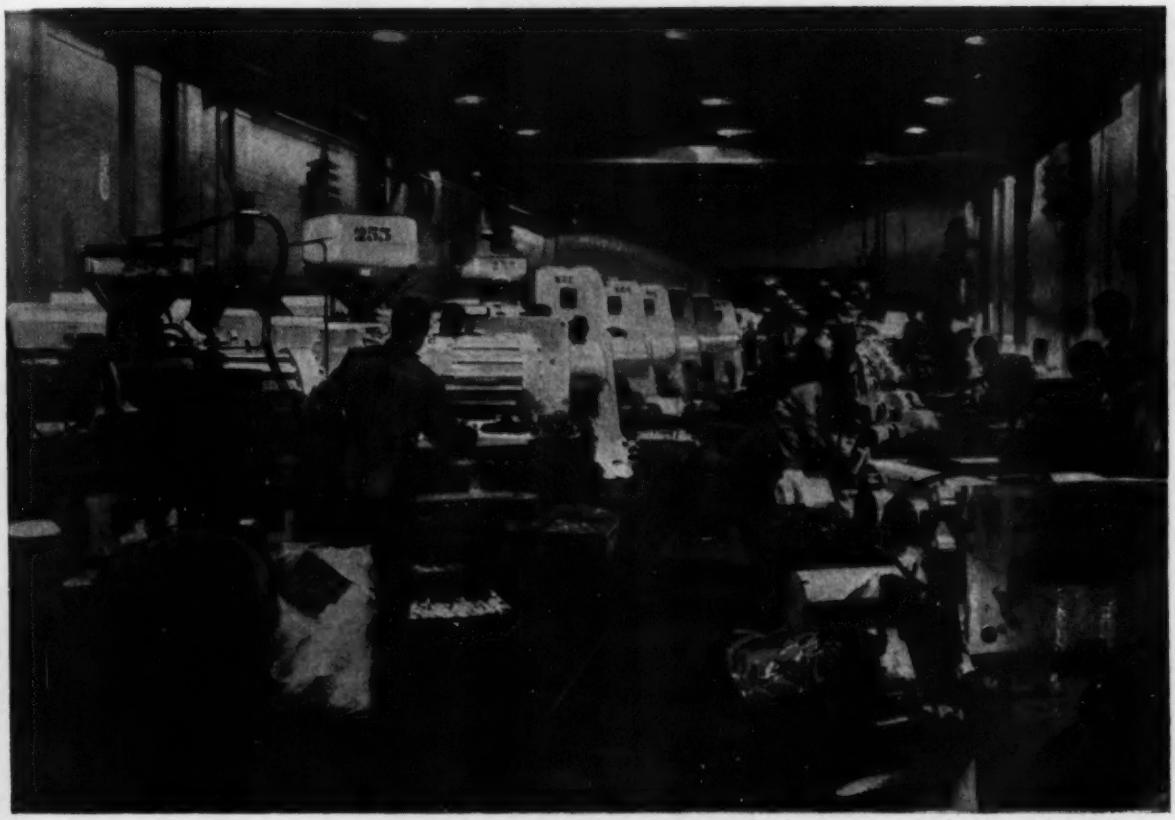


Technical Brochure from
JOHN FOWLER & CO (LEEDS) LTD Sprotborough Foundry, Sprotborough, Doncaster

the STREETLY line . . .



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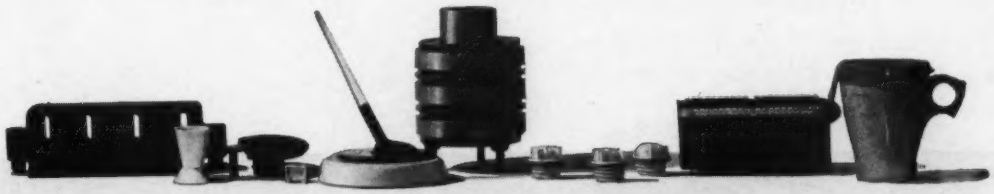
Streetly is equipped for the mass production of plastics mouldings to a high standard of accuracy and finish in all materials. The key lies largely in modern press plant and scrupulous supervision by highly skilled technicians.

Over a period of many years Streetly has built its reputation on this technical skill and reliability. The best measure of Streetly service is the status of its customers and the length of their mutually satisfactory associations.



STREETLY MOULDINGS

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It's team work that counts

In most spheres of activity, ultimate achievement largely depends on team-work, and just as the successful racing driver relies on the efficiency of the men in the pits, so the final perfection of your products depends on team-work through all stages of manufacture. Weathershields have a team with the "know-how" and experience to co-operate with you in design, development, manufacture and service to achieve maximum output.

FABRICATED and WELDED ASSEMBLIES, PRESS WORK, GLAZED UNITS, SHEET METAL WORK

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H-W.157

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they stand on

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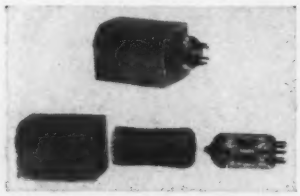
KnitMesh is knitted from one or more filaments in stocking form to a large range of interstice sizes and shapes. The more usual meshes are between 4 and 12 openings to the linear inch and from ¼" to 15" lay flat stocking width. Laminated or round wire can be used and the mesh can be crimped or pleated with a variety of crimp sizes and patterns, thus enabling control of surface area and free volume in different applications.

If you would like to know more about this unique material please write for fully descriptive literature.



KnitMesh Valve Jackets

KnitMesh valve jackets are being successfully used to disperse the heat generated by valve assemblies. The large amount of surface area created by KnitMesh, coupled with the close contact which, because of its resiliency it is able to make with the glass, means that the maximum amount of heat can be disseminated in a very short time—a process which considerably lengthens the life of the valve and often increases its normal power rating.

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SPECIALLY DESIGNED EQUIPMENT

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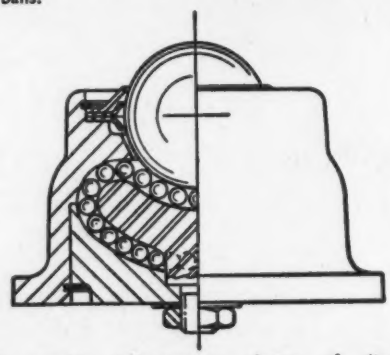
Omni-track Conveyor Ball Units having dynamic load capacities from 50 lb. to 5 tons each with ½" to 2" dia. load balls.



O.T.'s provide instantaneous change of direction automatically accommodated at any angle, with effortless ease. On cast iron or hardened steel plate starting effort may be as low as 1% of the gross load. Special rotary applications as low as 0·25% per gross load.
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6" tubular shank, 90-lb.

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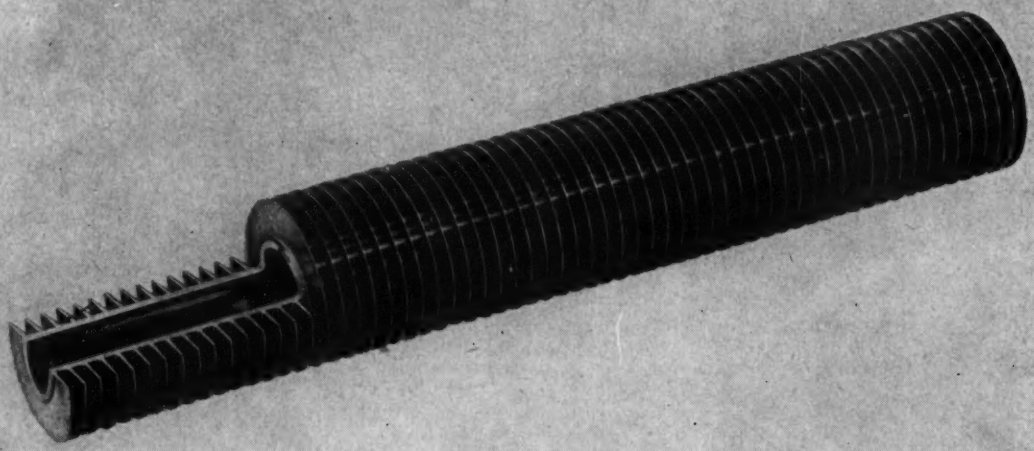

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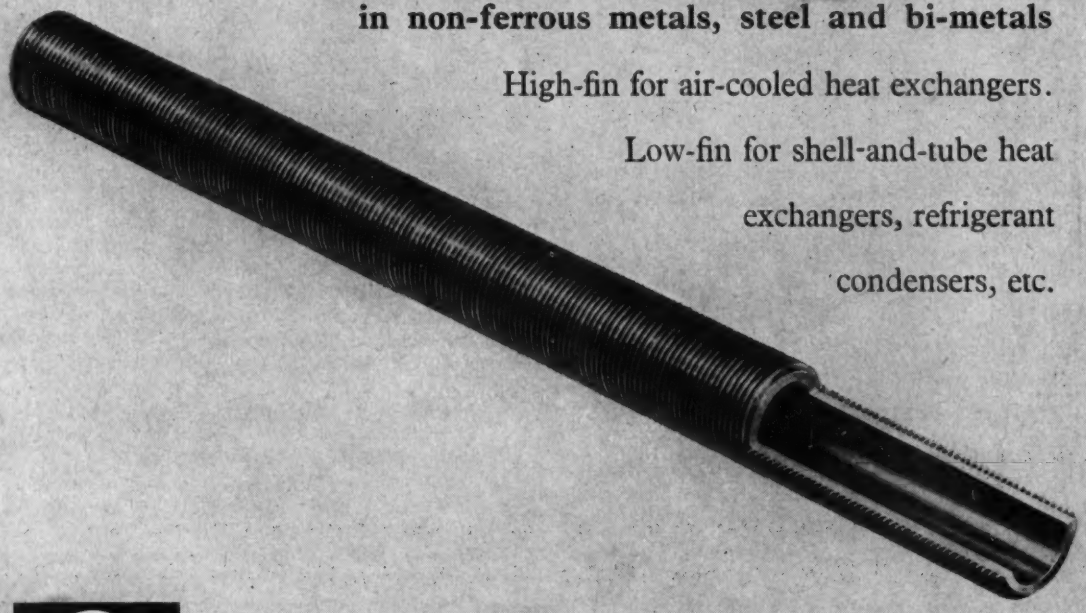
Low-fin for shell-and-tube heat exchangers, refrigerant condensers, etc.



ICI METALS DIVISION

IMPERIAL CHEMICAL INDUSTRIES LIMITED, LONDON, S.W.1.

M.464/8

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a silicone rubber that's easy to cure and simple to use....

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- *High thermal conductivity.*
- *Protects against moisture, dust, oxidation, weathering, ozone, corona and mechanical shock.*

Silastomer is the registered trade name of a comprehensive range of silicone rubbers manufactured and marketed by Midland Silicones Ltd.

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To give you information on all the properties and applications of Cold-Cure Silastomer, we have prepared a fully detailed and illustrated booklet. Please write or phone our nearest branch office for a copy.

MSR8a

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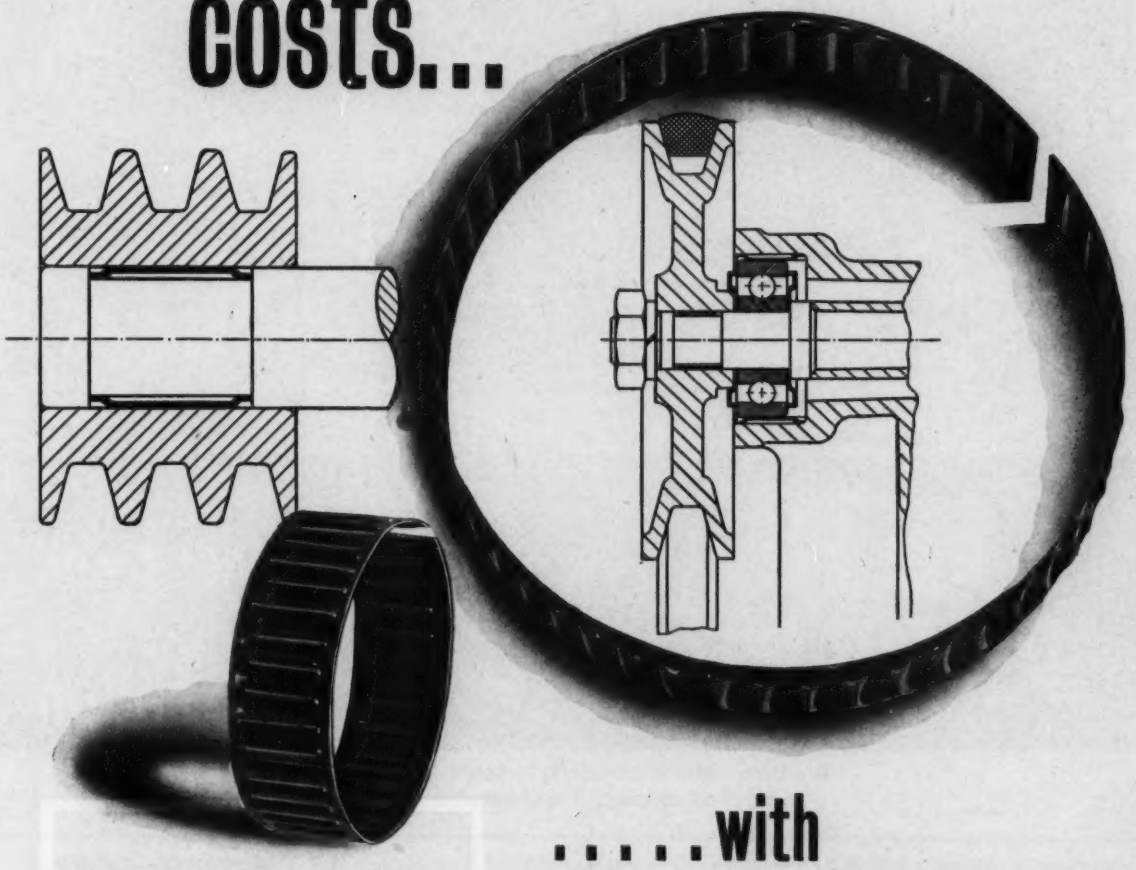

Available in a wide selection of sizes Star Tolerance Rings provide simple efficient means of fixing:

- **Lever knobs, handles, etc.**
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- **Ball or roller bearings in housing bores.**

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.....with STAR TOLERANCE RINGS

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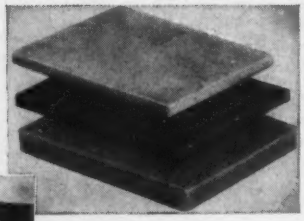

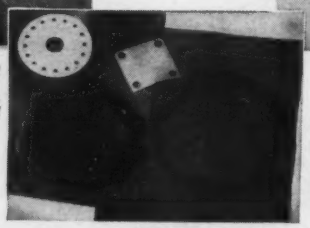

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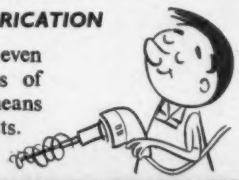

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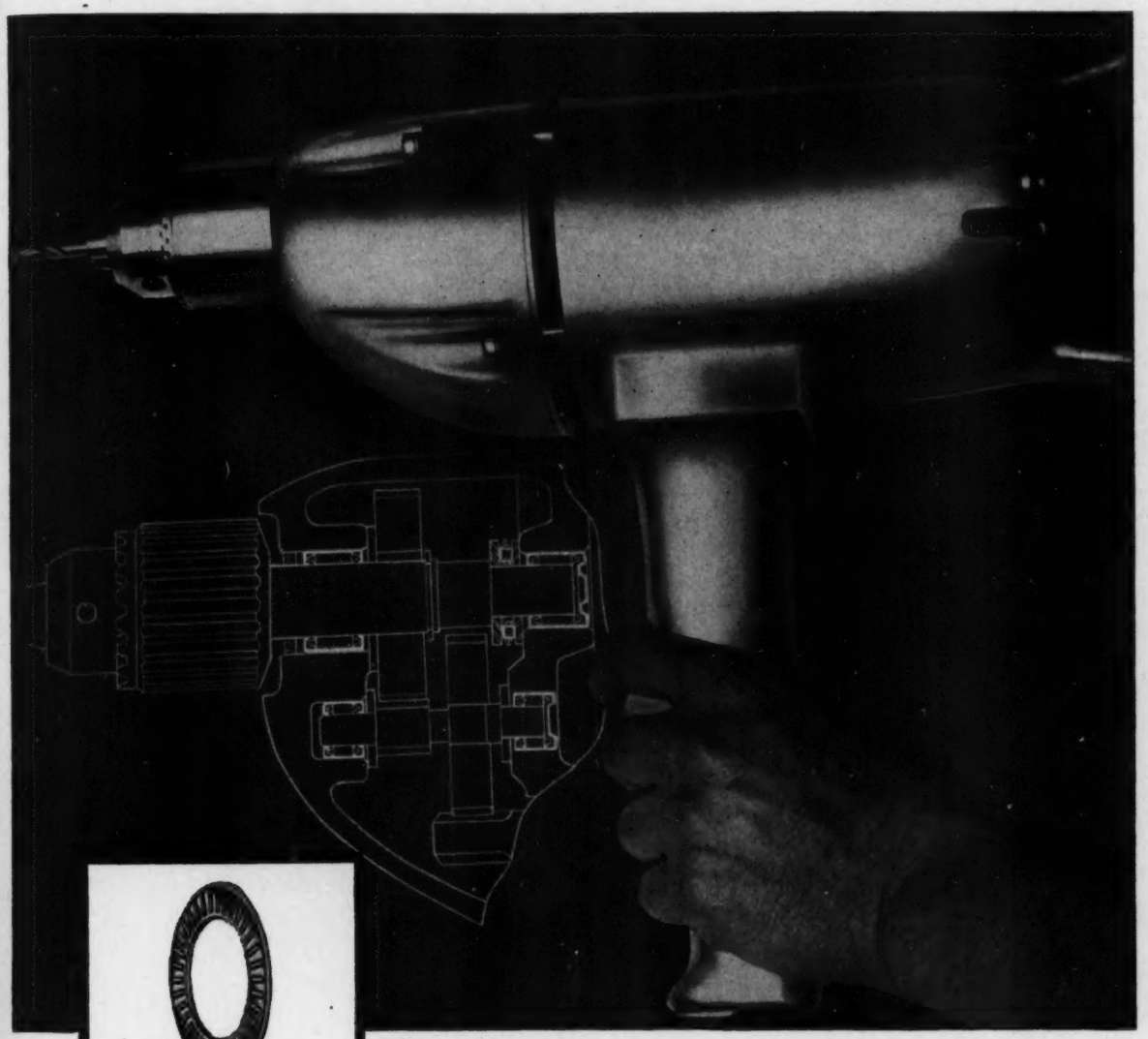

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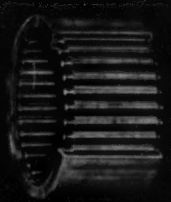

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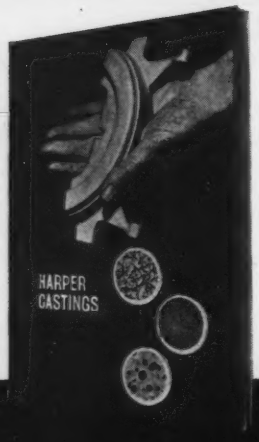

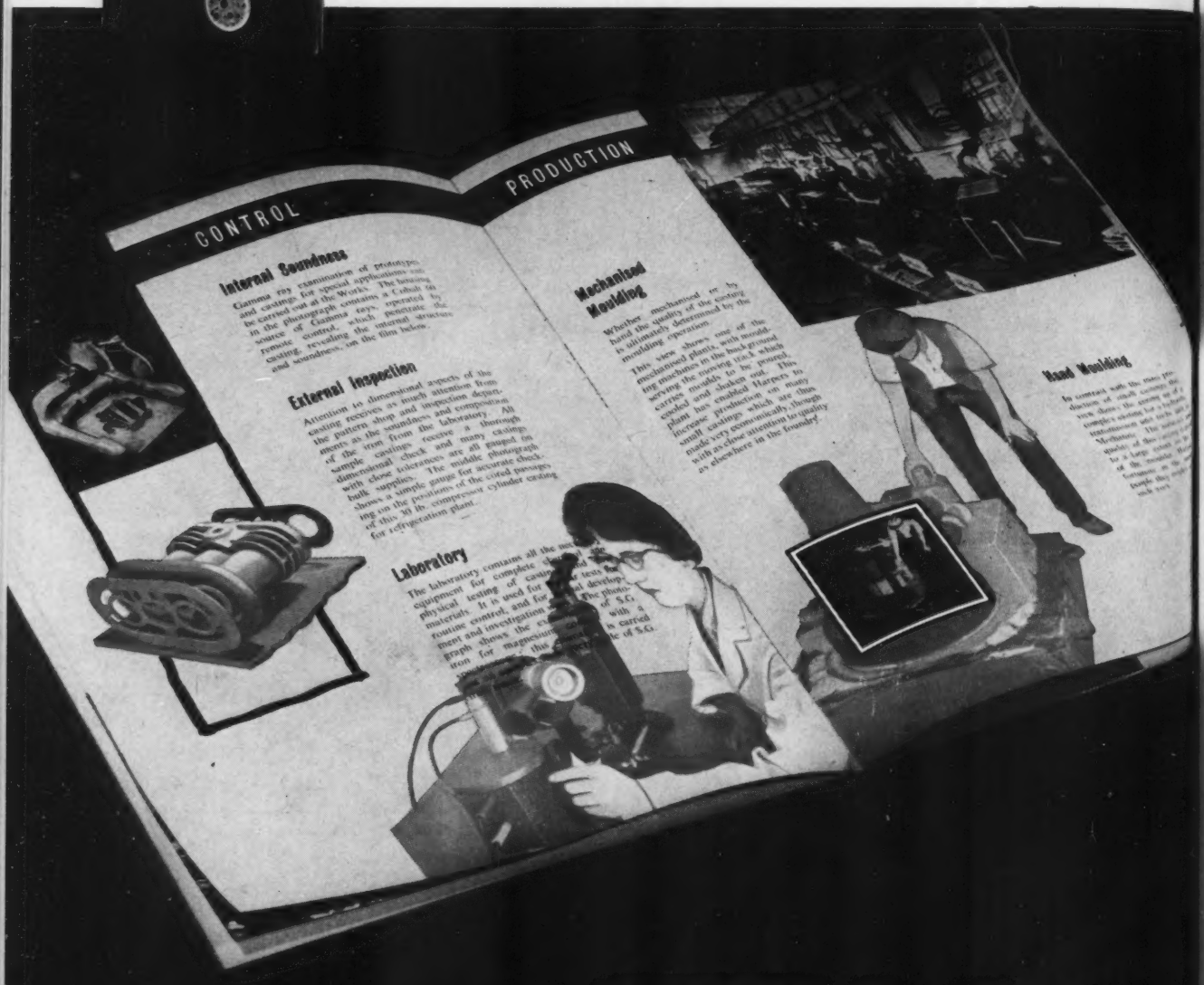

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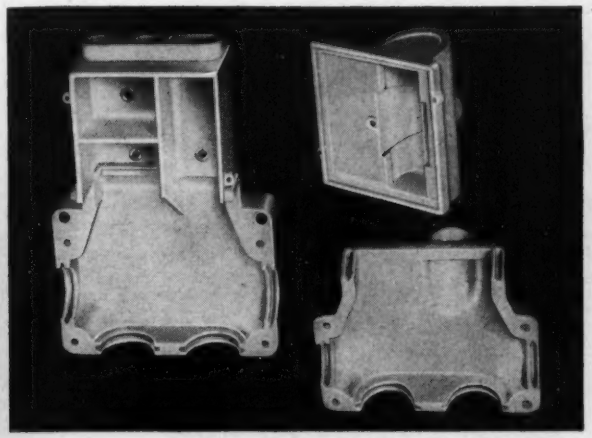

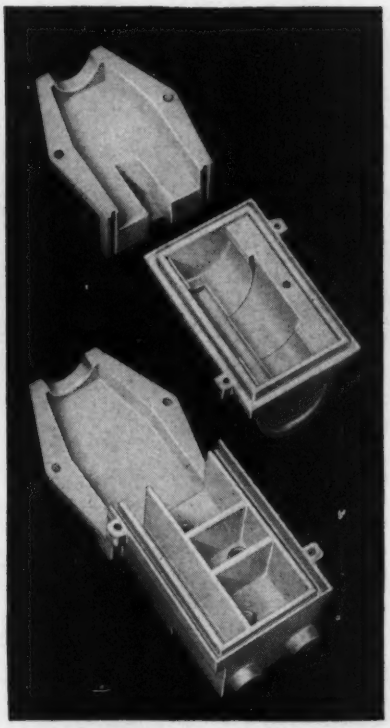

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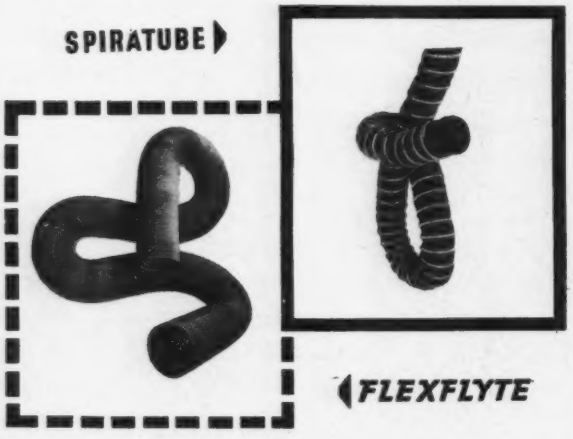

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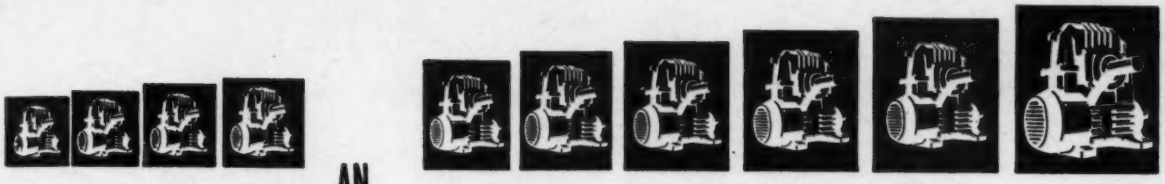

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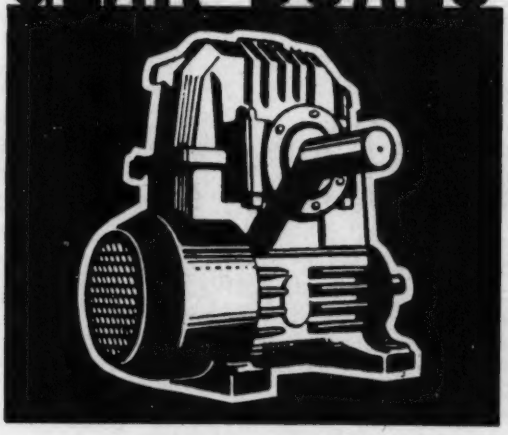

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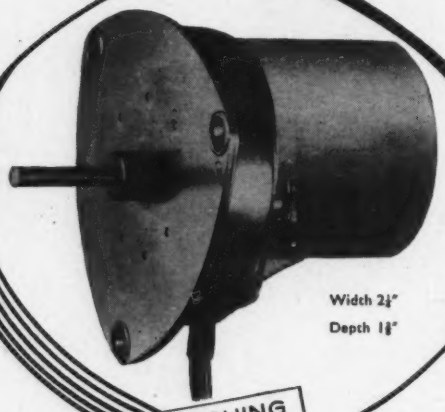

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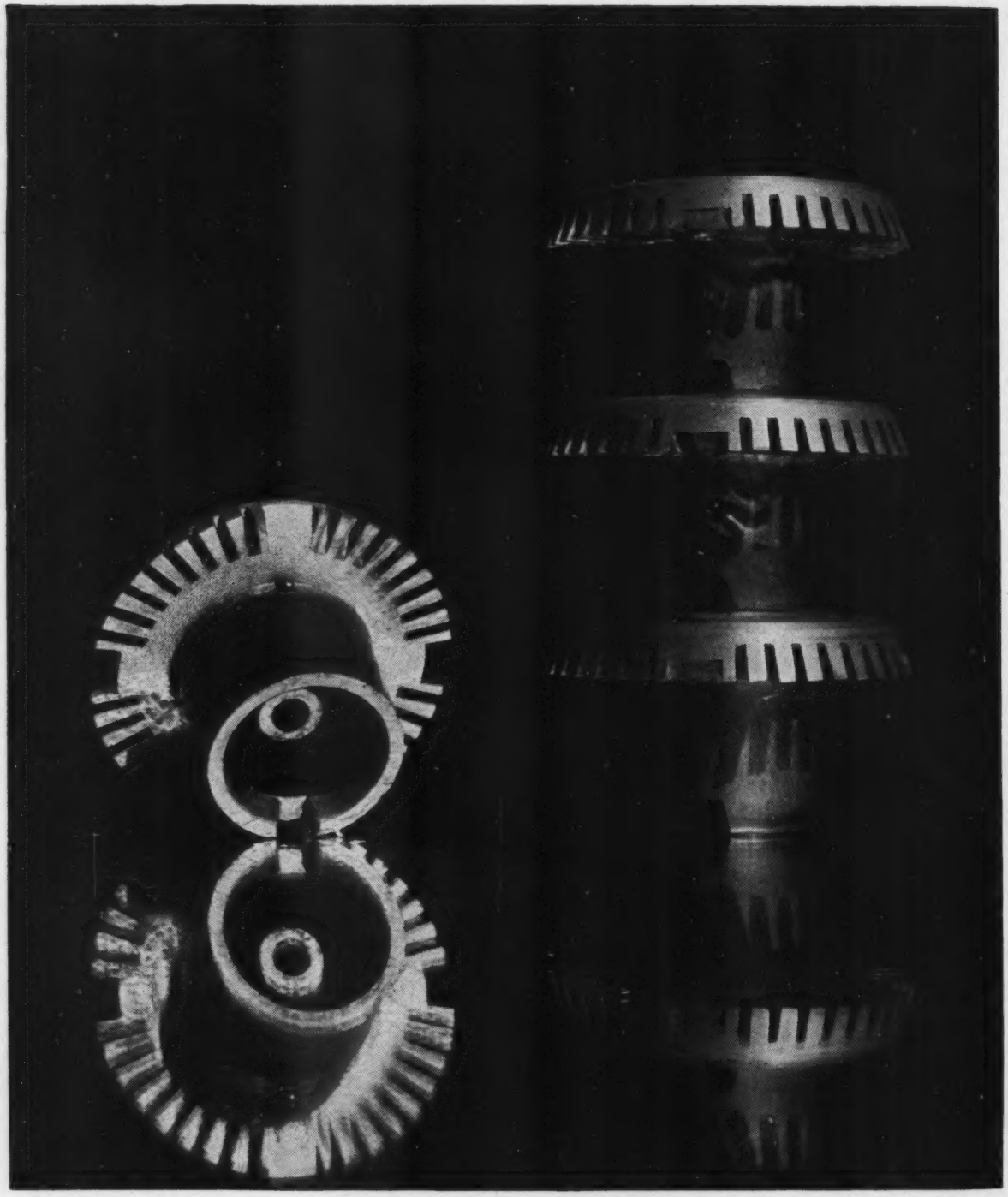

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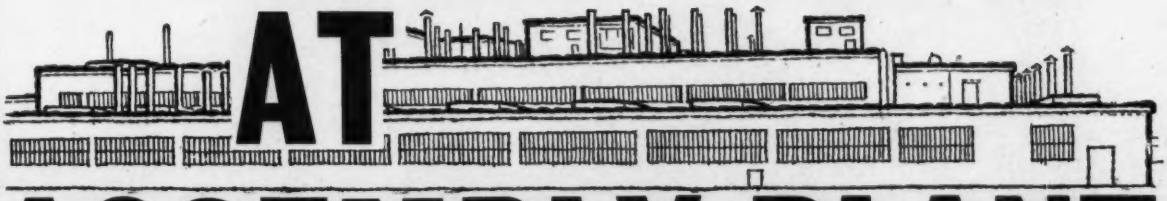

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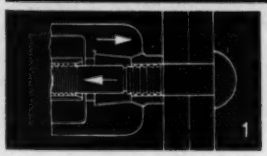
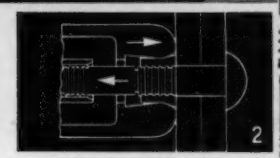
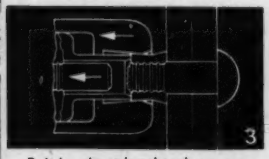


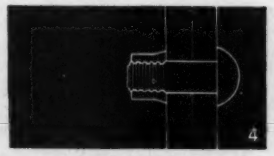
High clenching action clamps sheets together.



Collar swaged and locked into grooves.



Bolt breaks at breakneck groove.



Installed lock bolt

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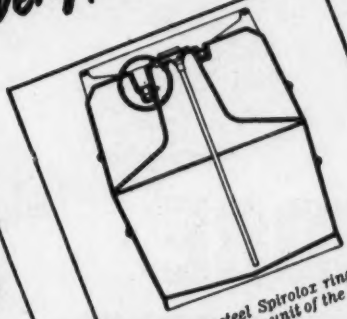

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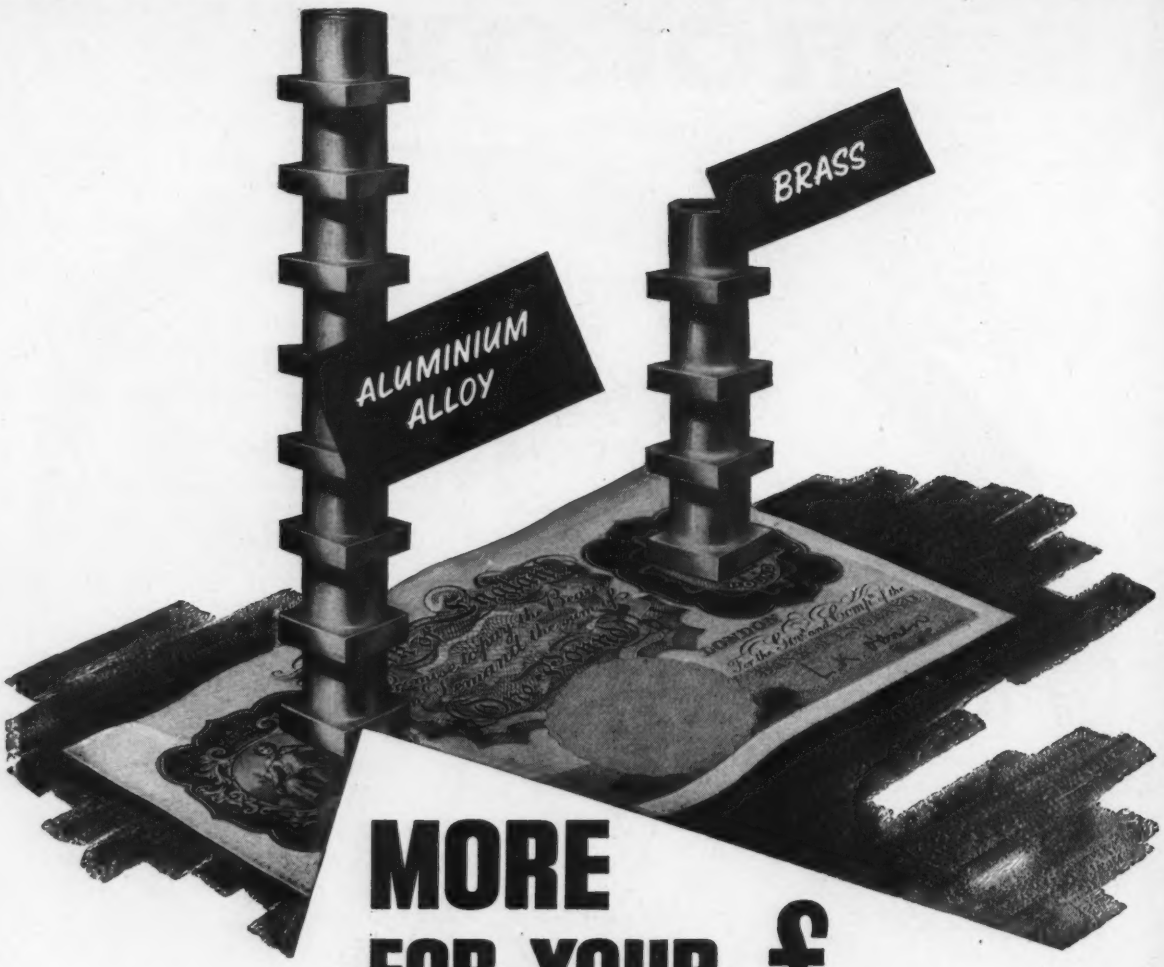

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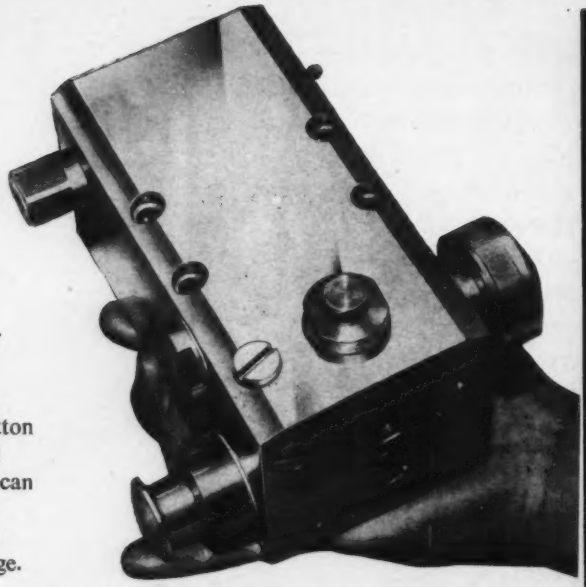

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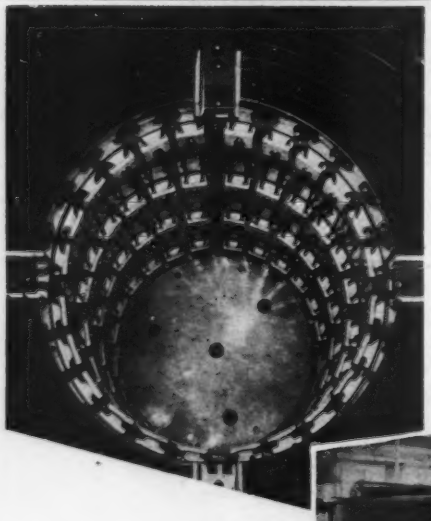

(Above) A close-up of molybdenum heater showing the concentric radiation shields.

(Right) RH40 vacuum brazing furnace (Photograph by courtesy of Joseph Lucas Ltd.)

Above the limit of size and temperature imposed by suitable refractories or metal containers, radiant-heated furnaces are employed. The furnace illustrated is used mainly for the vacuum brazing of high-temperature alloys up to a temperature of 1300°C. It employs a radiant heater comprising radiation shields, which take the place of the normal refractory thermal insulation, and a molybdenum wire resistance heater supported from an internal framework by high-quality alumina insulators. The furnace has an evenly heated zone 15in. diameter × 20in. deep, in which complete assemblies can be evenly heated to brazing temperature and multiple joints simultaneously brazed without distortion and the need for subsequent cleaning.

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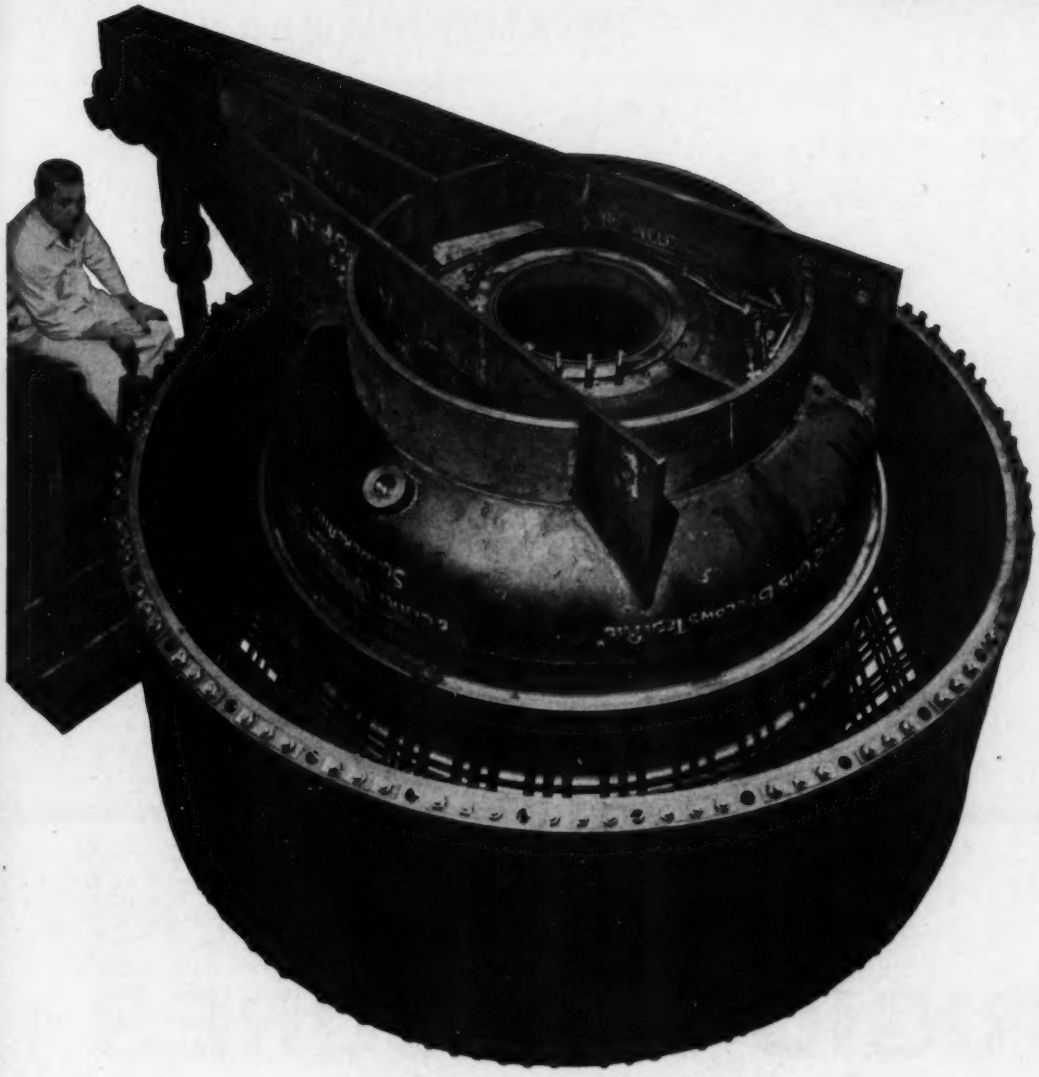

WELL, WHAT IS IT?

(To be fair we should point out that the domed top and fabricated cantilever are part of a test rig. The thing in question begins at the weld below the lettering).

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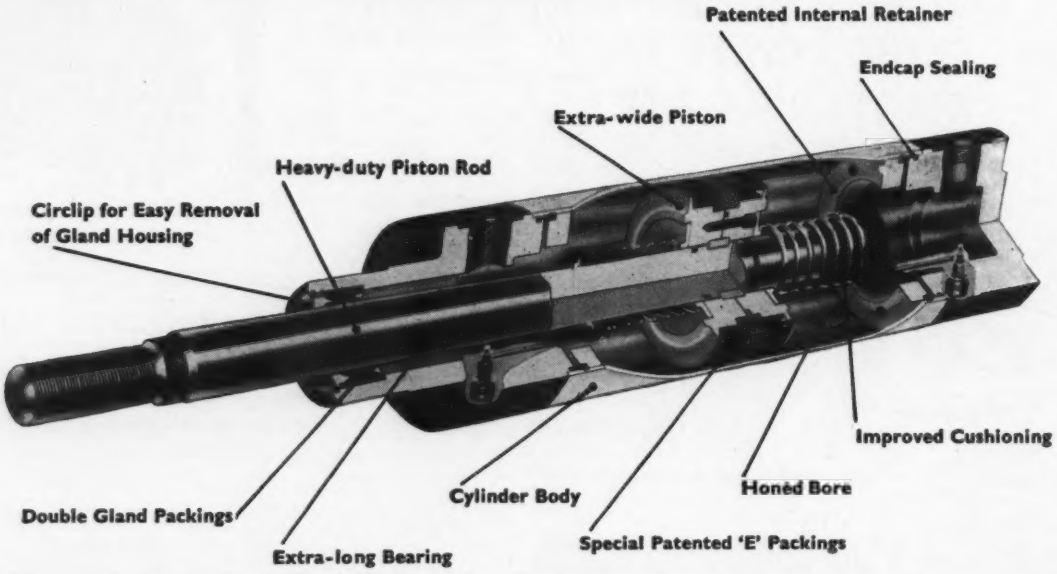

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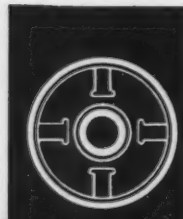

nylon at its best is called

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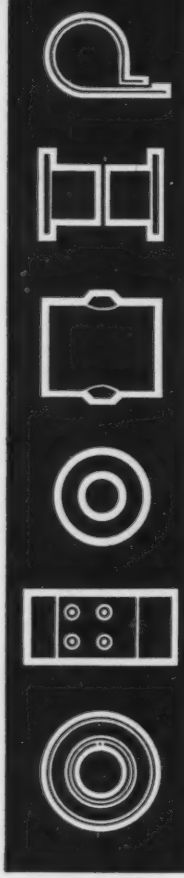

The Nylastic bearing is now firmly established as the ideal bush for swivel arm and lever applications. Nylastic is also used for steering joints, diesel fuel pump coupling discs, chain reaction pads, cable support clips, and is used with combinations of rubber and metal for steering column bearings, anti-vibration clips, earthing clips etc.

The experience gained over the past years enables us to give a unique service in advice and design for this increasingly popular material. Our Technical Staff is available to give you information and suggest schemes for your particular applications.

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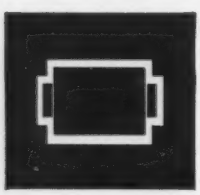

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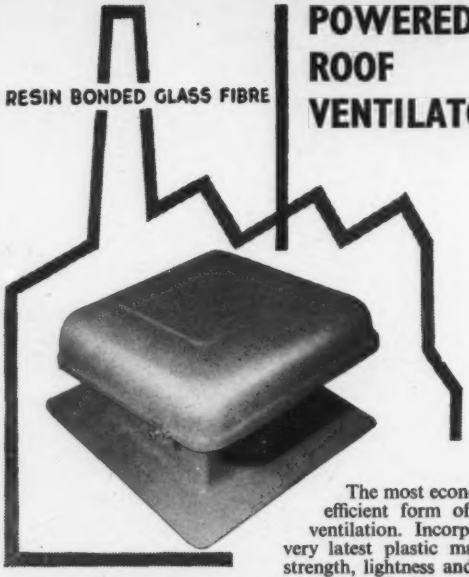

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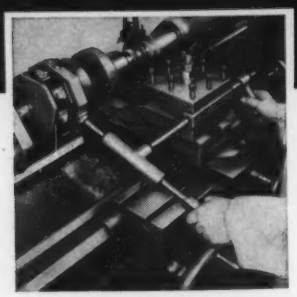

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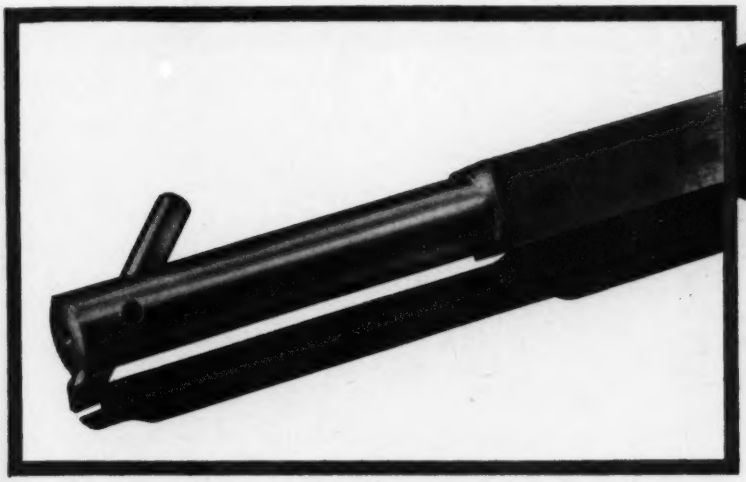
MALLORY high density materials aid production and design



MALLORY NO-CHAT

gives better, faster machining

Mallory NO-CHAT is ideal for boring bars, parting tool shanks and grinding quills for use in applications where tool chatter must be minimised and machining must be fast, economical and accurate.

Mallory NO-CHAT, a recently developed vibration-damping tool shank material, greatly reduces tool chatter. In both tool-room and machine shop it offers:

- ★ **Increased cutting speeds without loss of finish**
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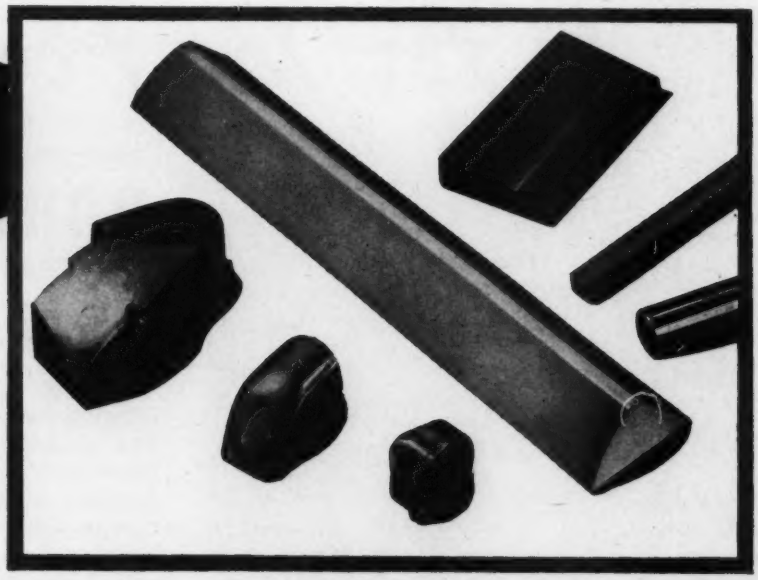
MALLORY 1000

puts more weight into less space



A new high-density sintered material, Mallory 1000 has a unique combination of physical characteristics. In applications ranging from counterbalances for aircraft control surfaces to rotors for self-winding watches, Mallory 1000 offers:

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Data sheets giving detailed technical information on Mallory NO-CHAT and Mallory 1000 are free on request.

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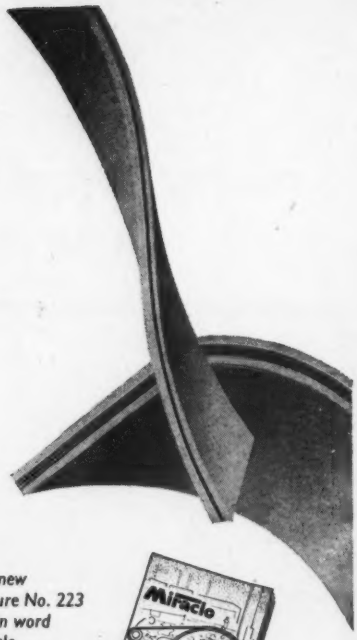

- ★ **Flexibility**
- ★ **Grip**—with chrome leather driving face
- ★ **Virtually no stretch**
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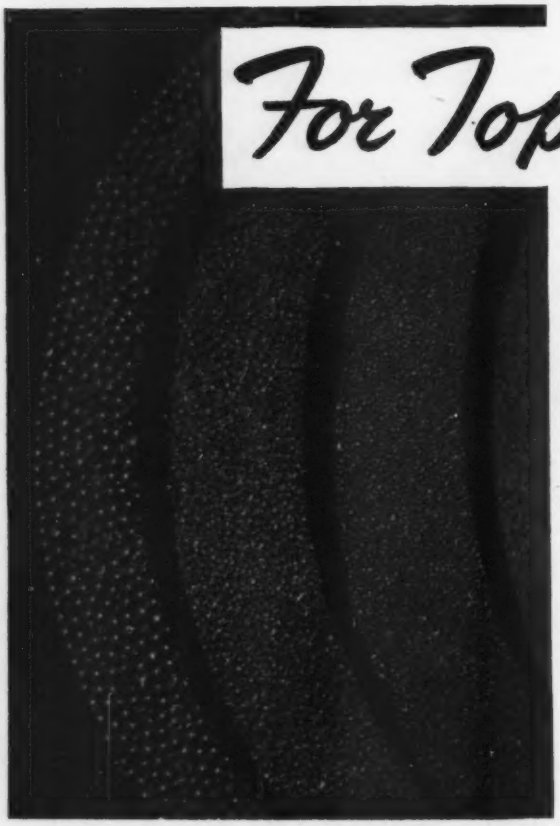

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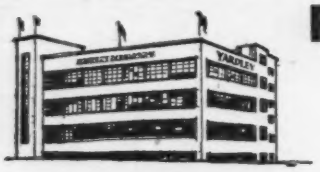
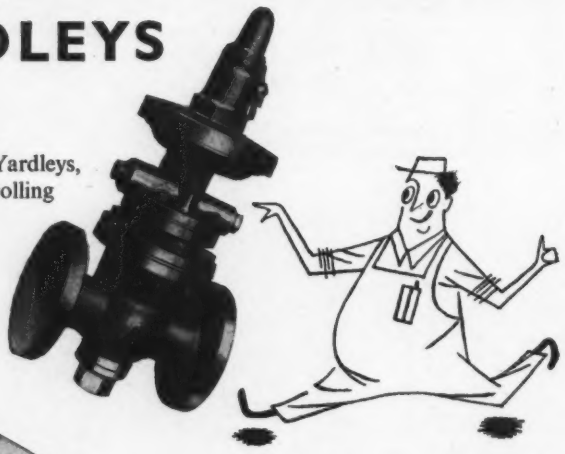


Relying on Bailey's valves —YARDLEYS



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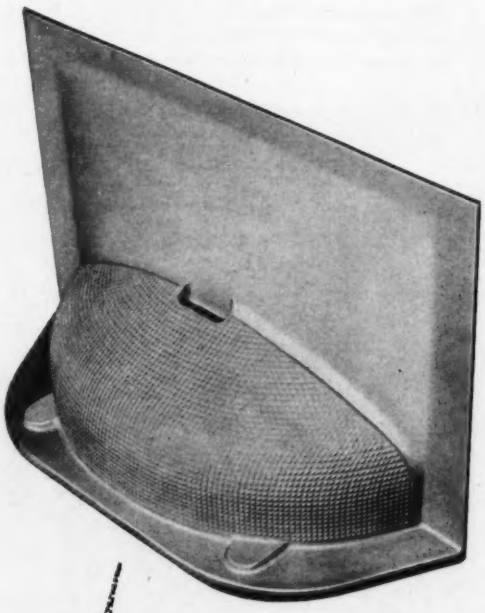

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Weight 14 lb.
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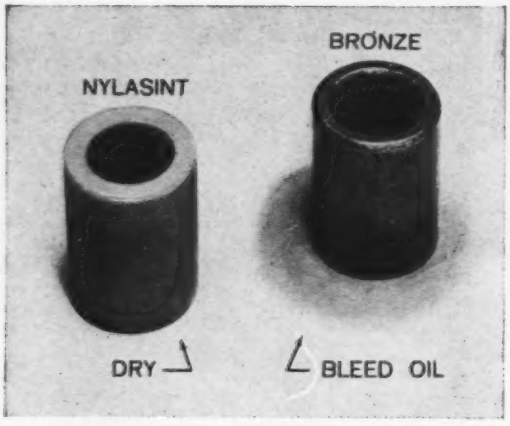

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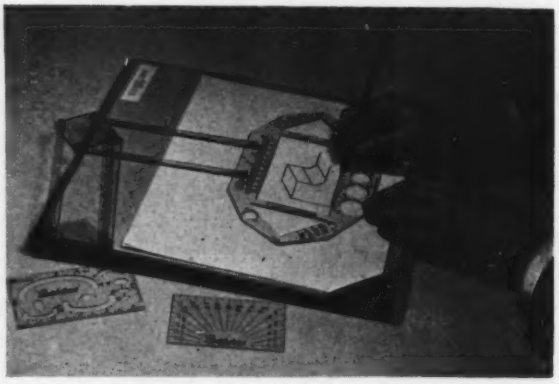

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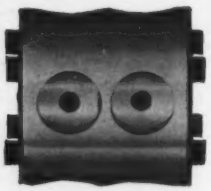

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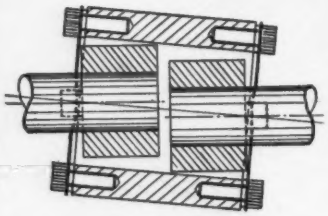
says J. E. Hawkins of SOLARTRON



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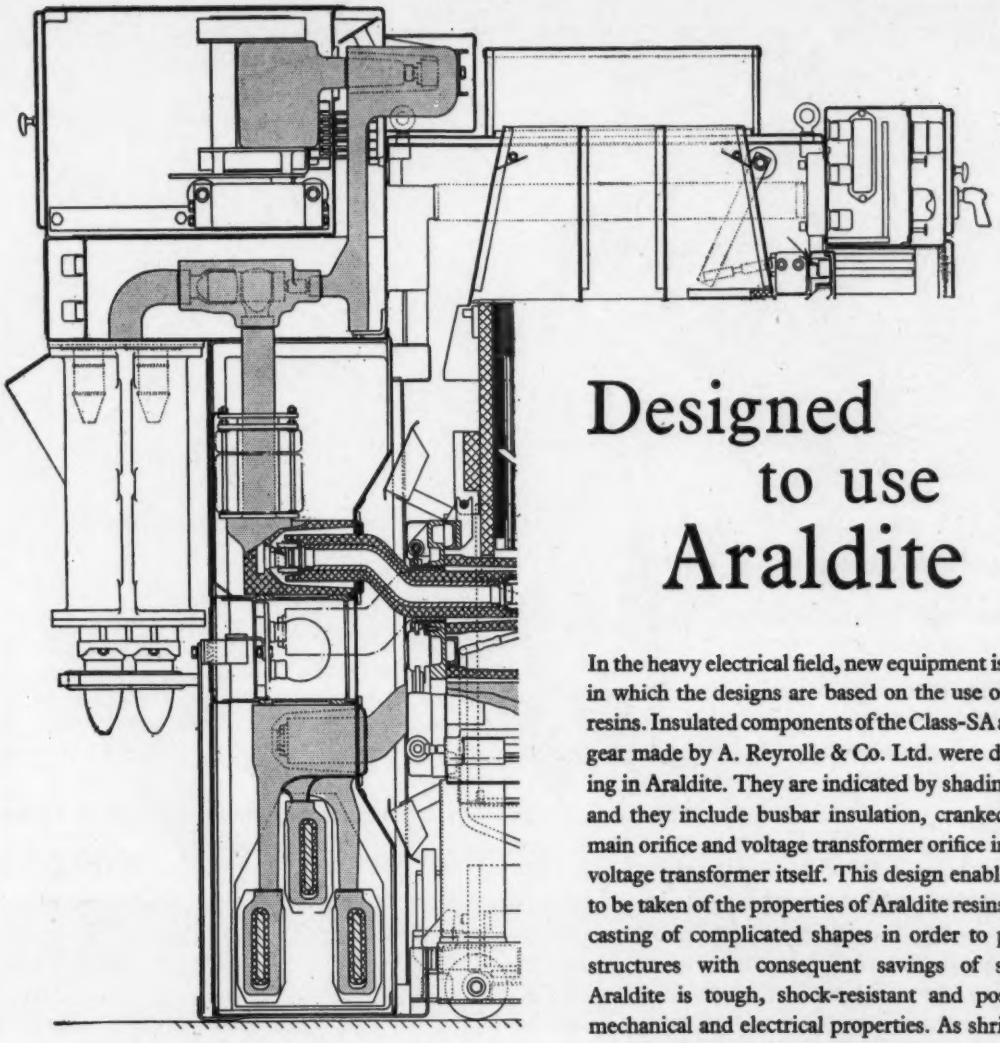

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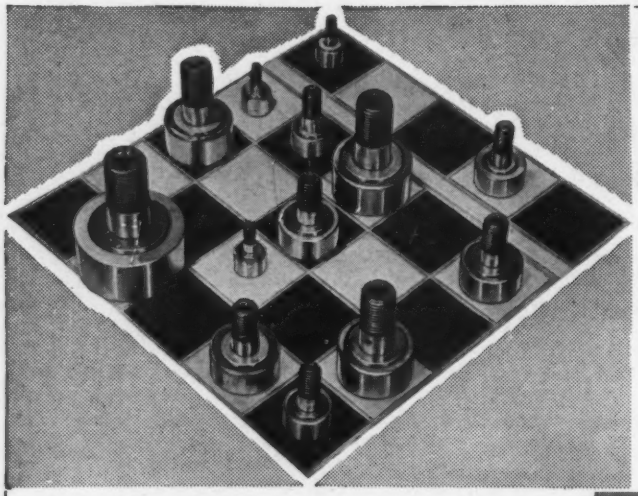
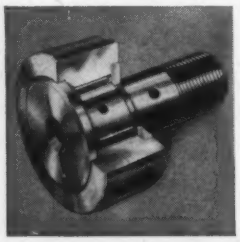


No problem with Ina cam followers



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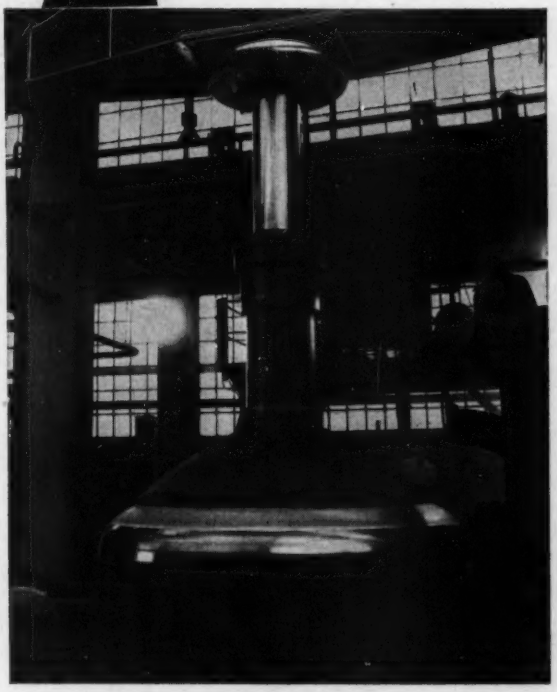

The Rotarpress is one of the large-capacity units in Harveys Heavy Fabrication Department. It produces ends up to 15 ft. diameter and is adaptable over a wide range of knuckle radii and depths.

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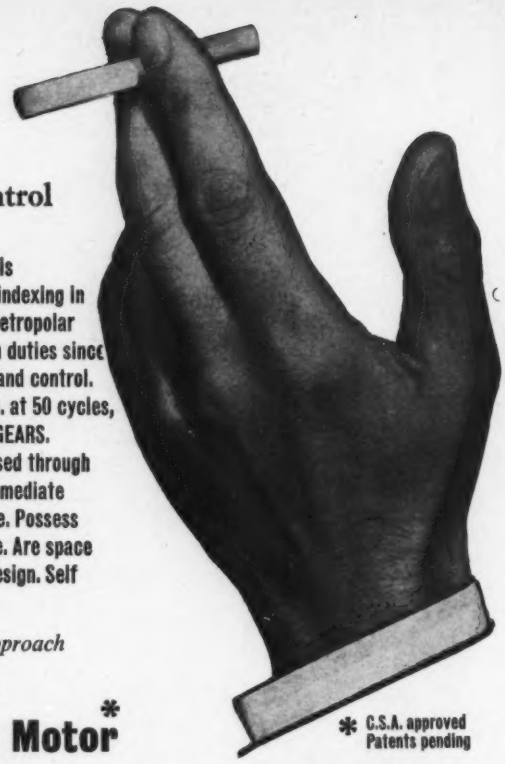

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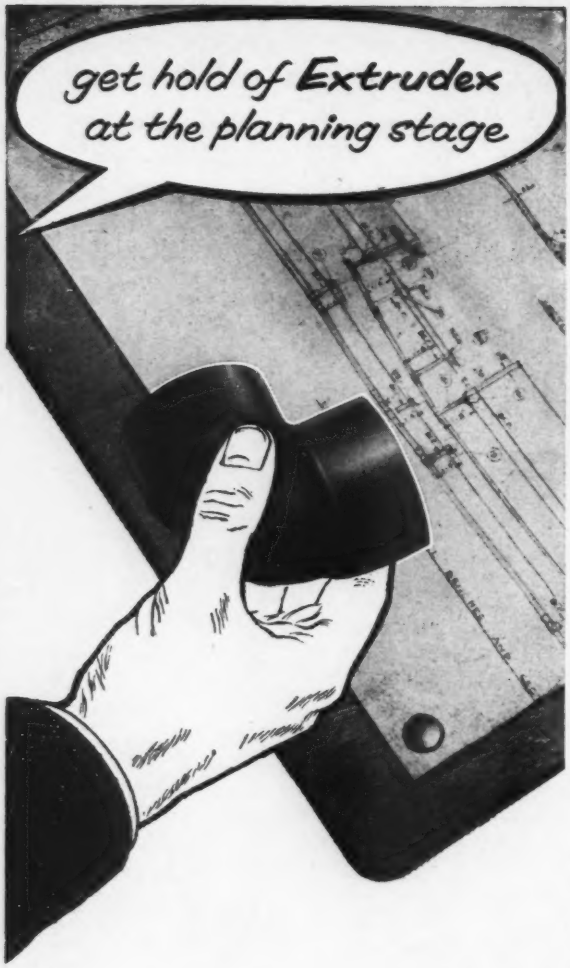

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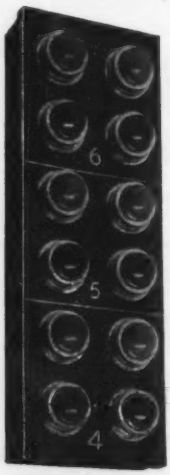

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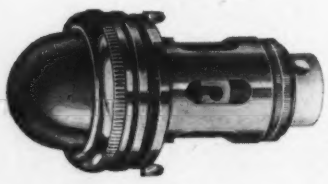

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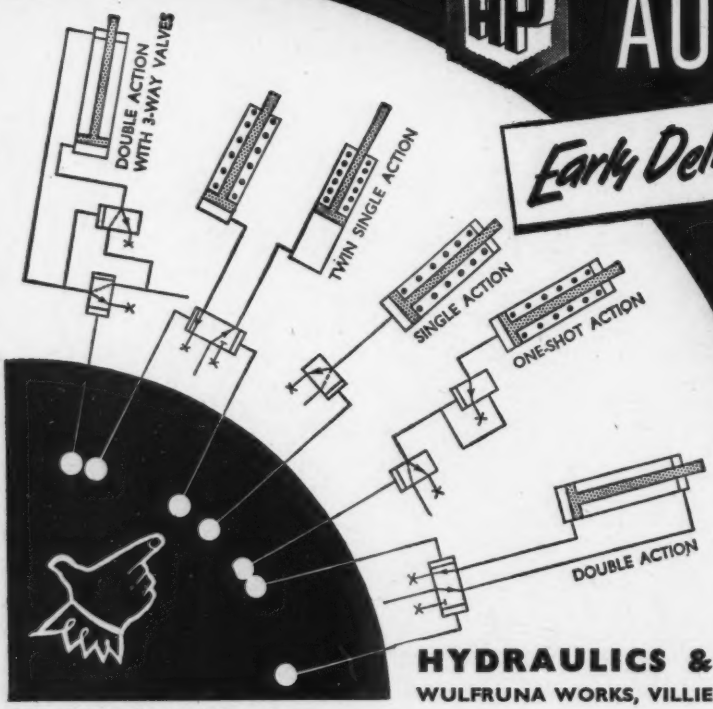

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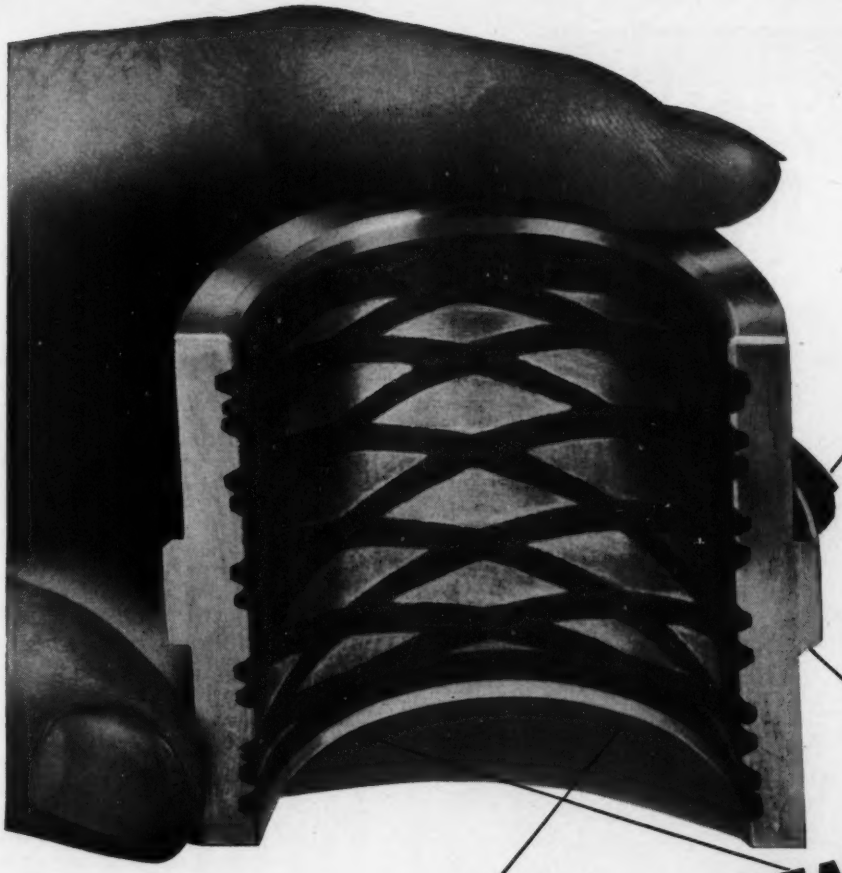

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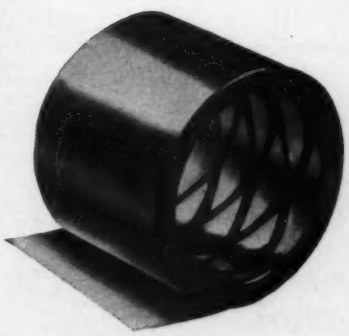

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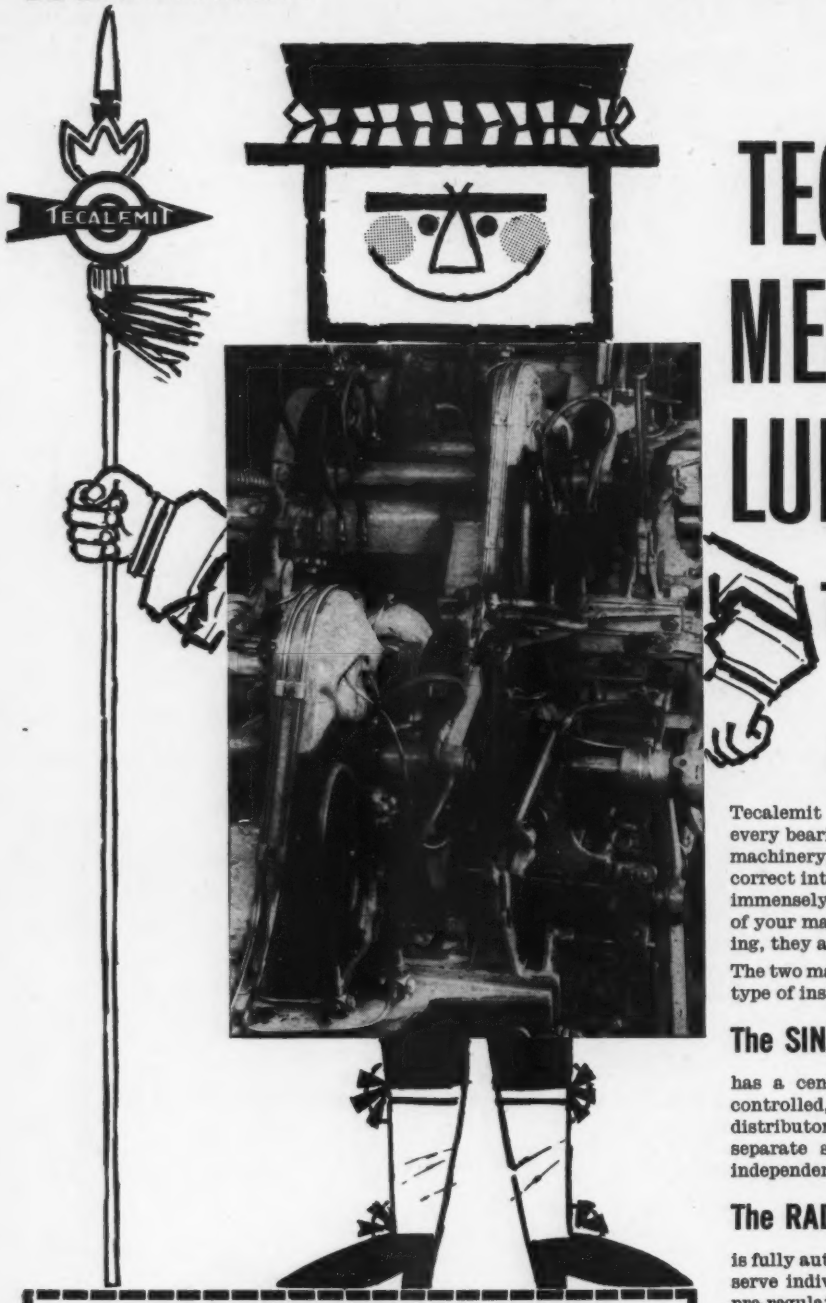

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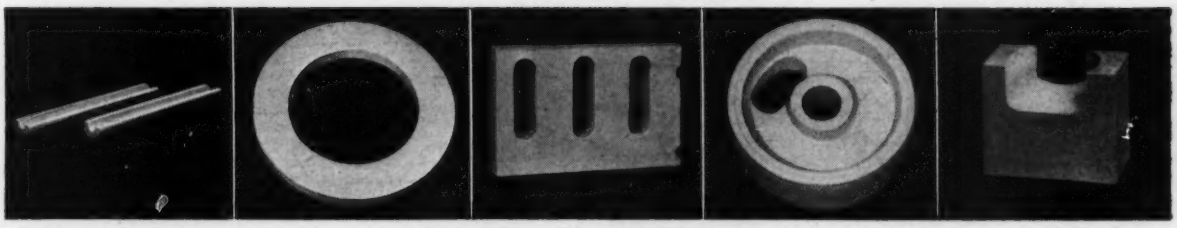

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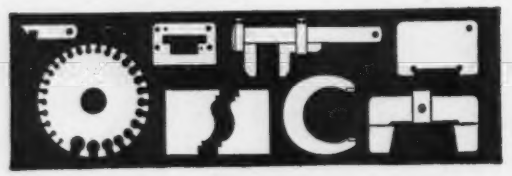

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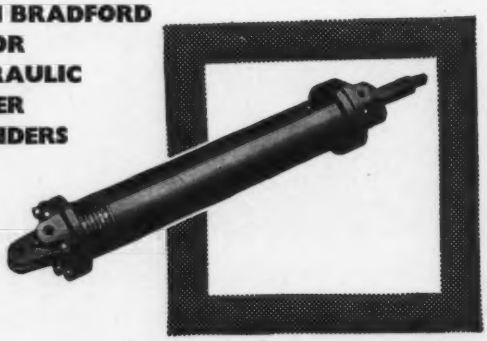

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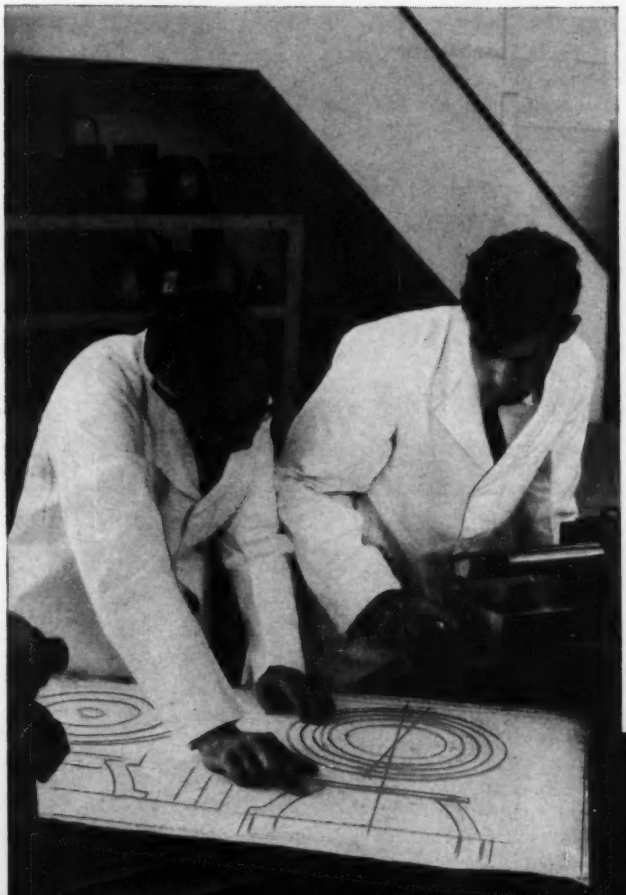

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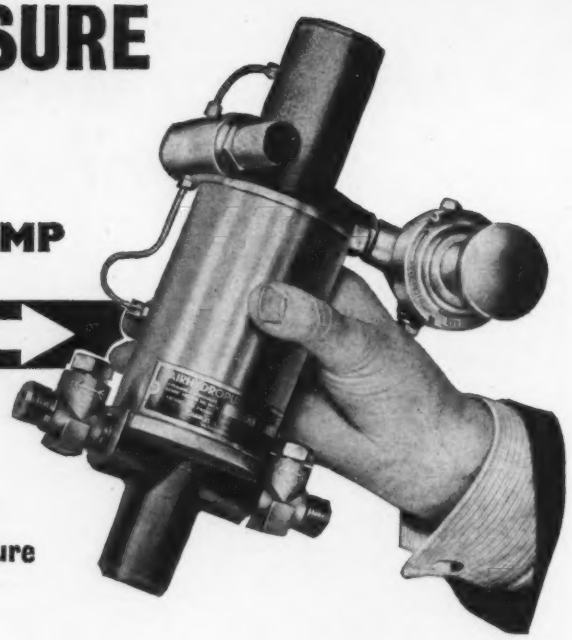

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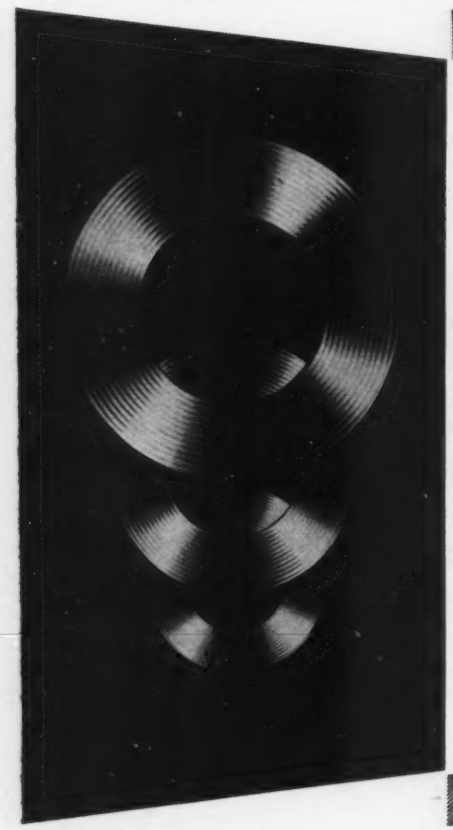

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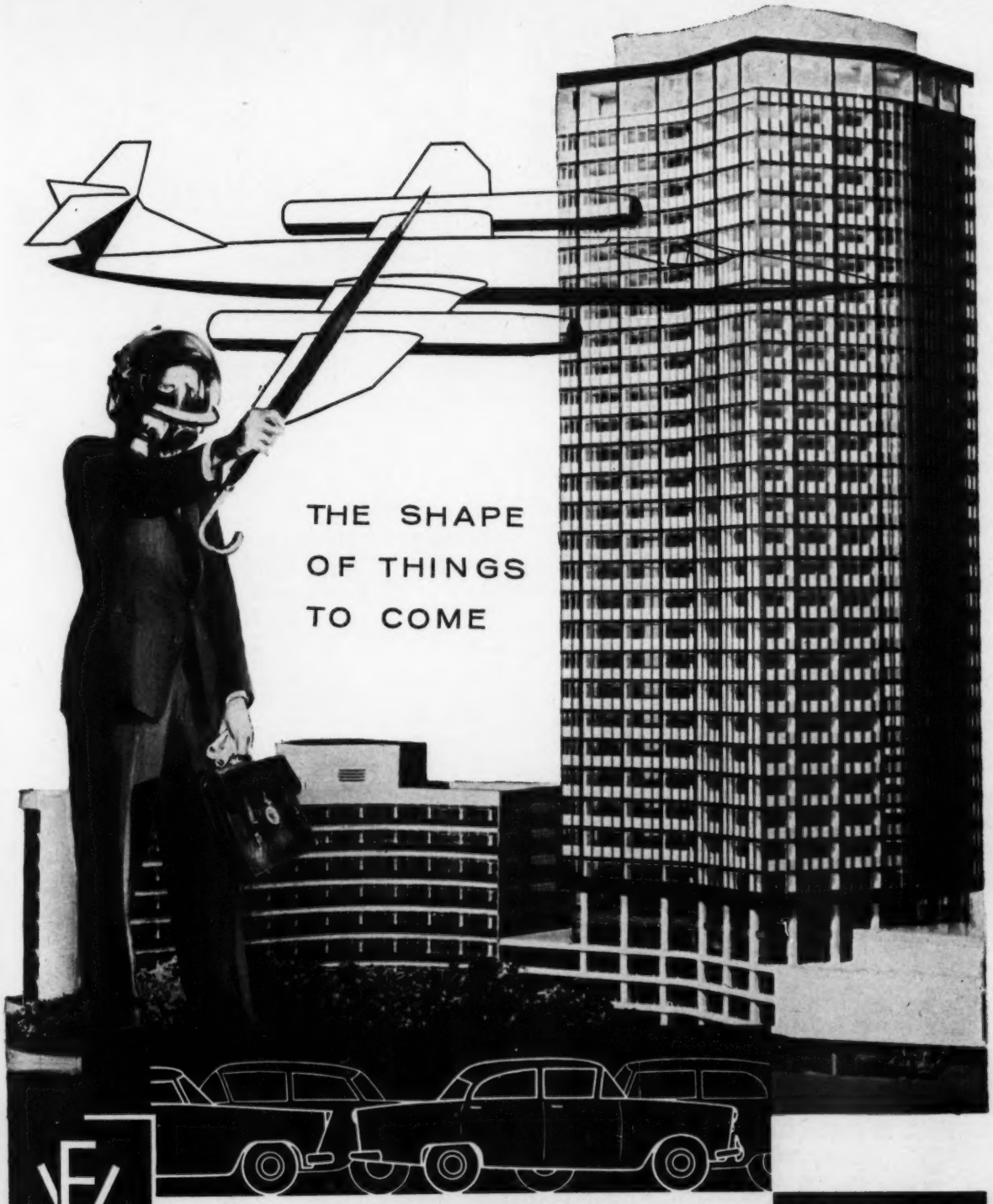

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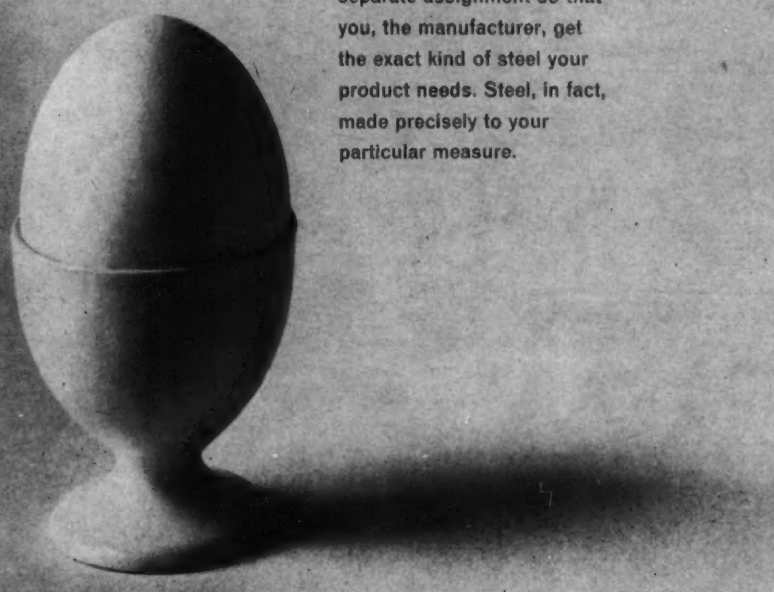

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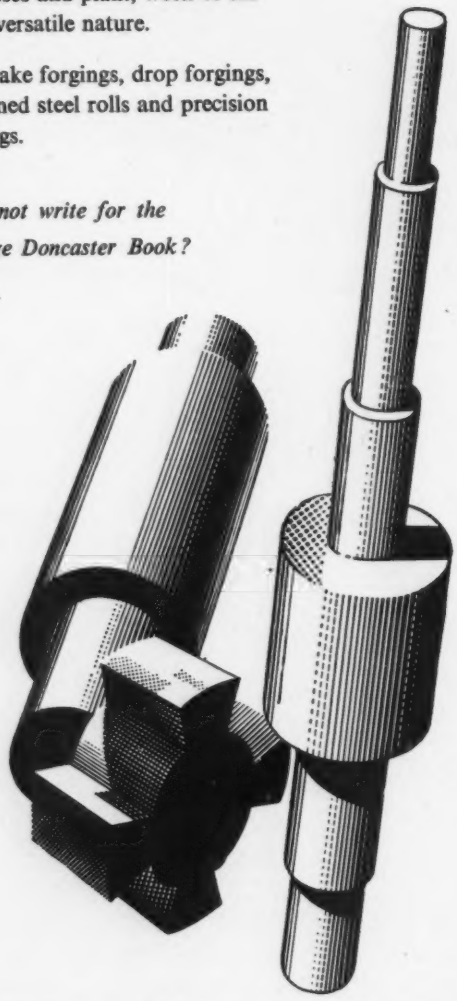

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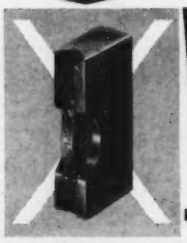

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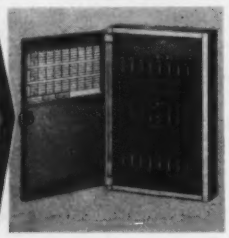

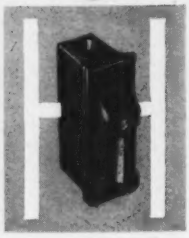

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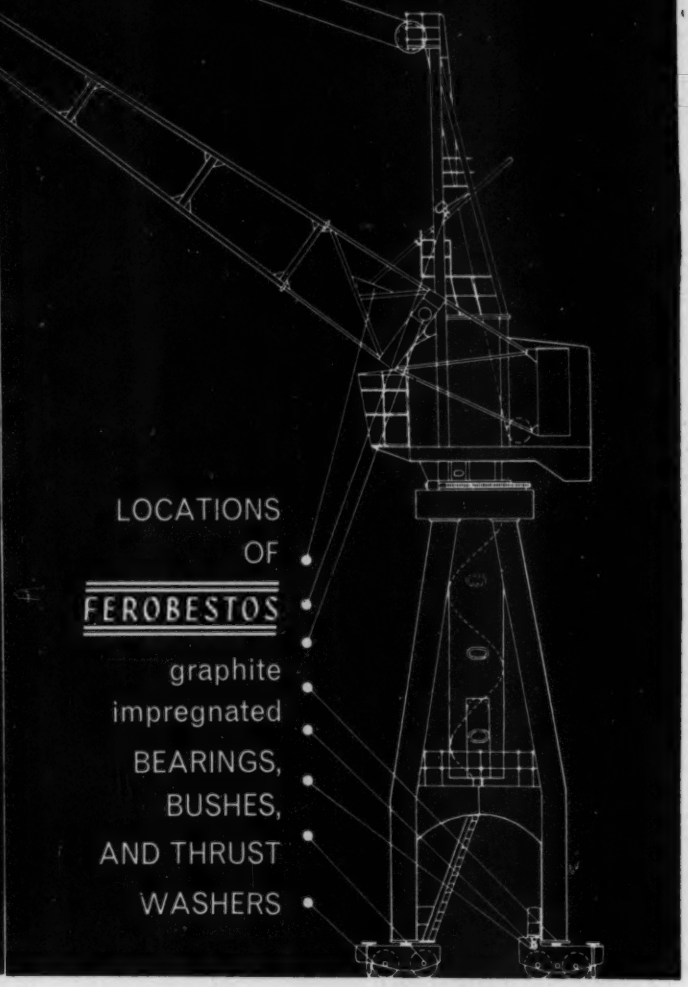

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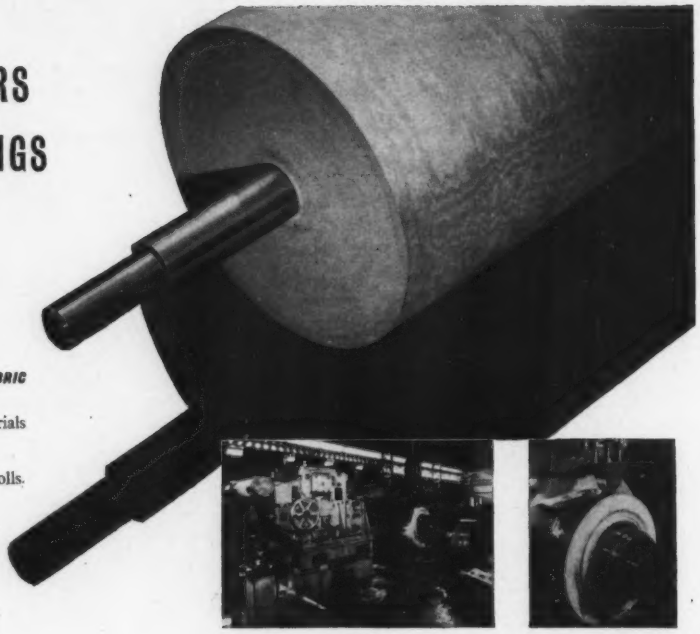

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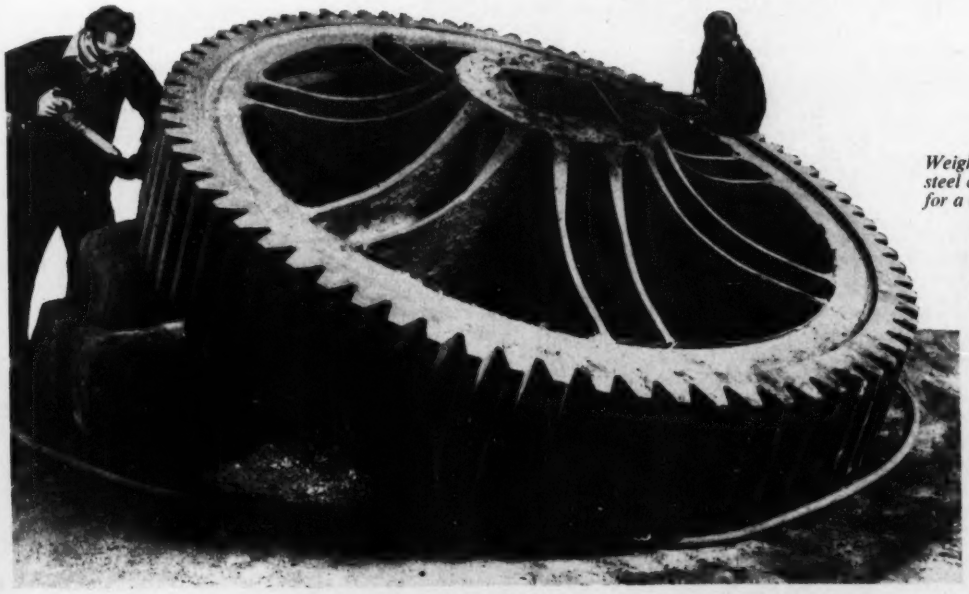

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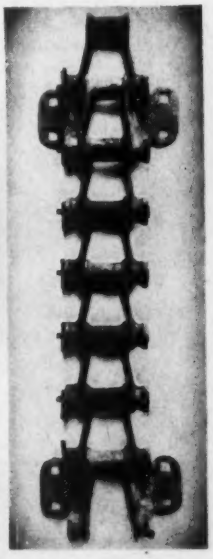

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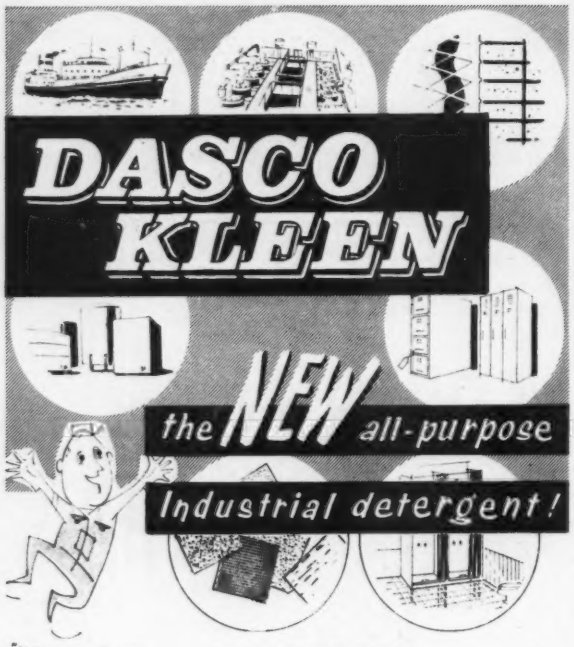

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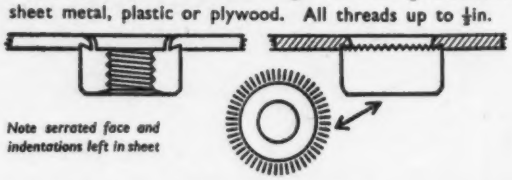

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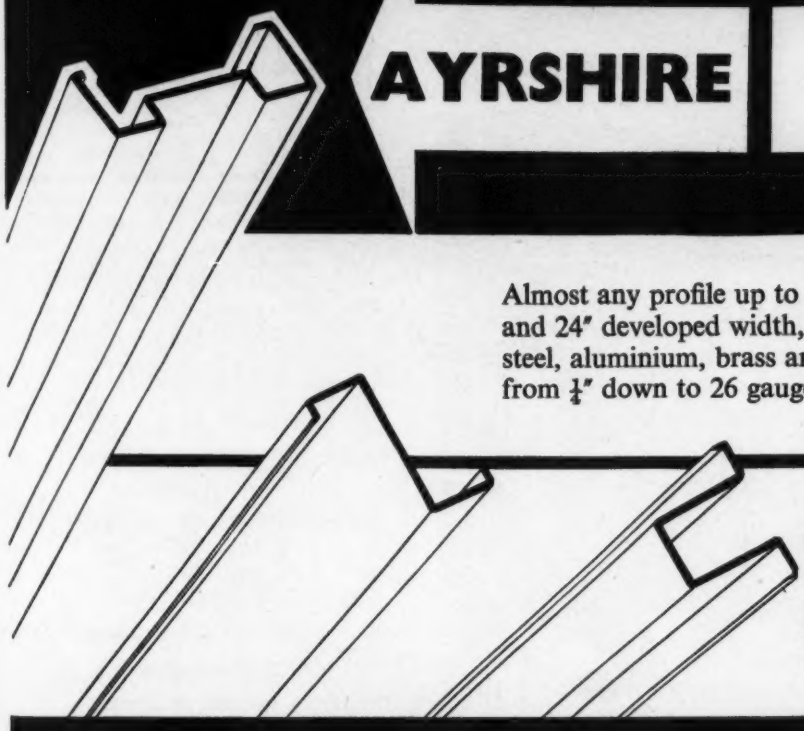

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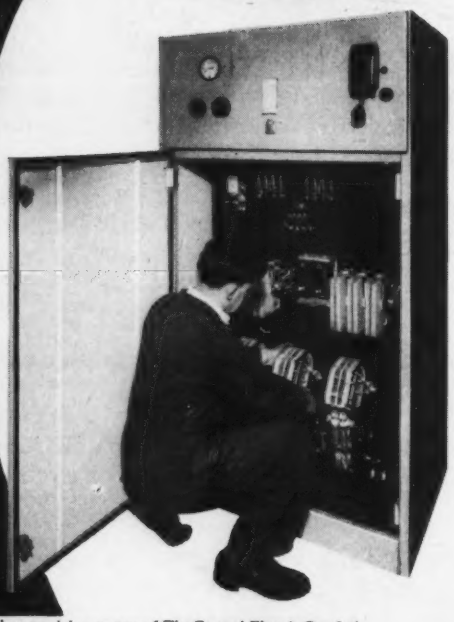

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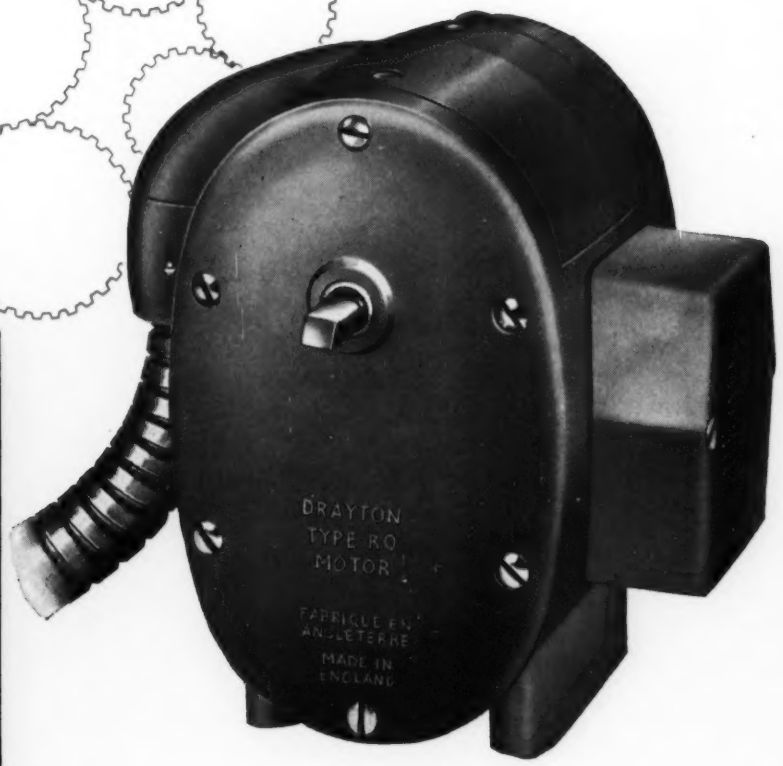

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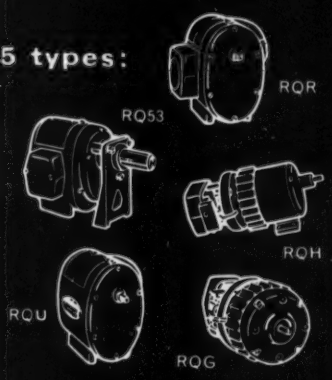

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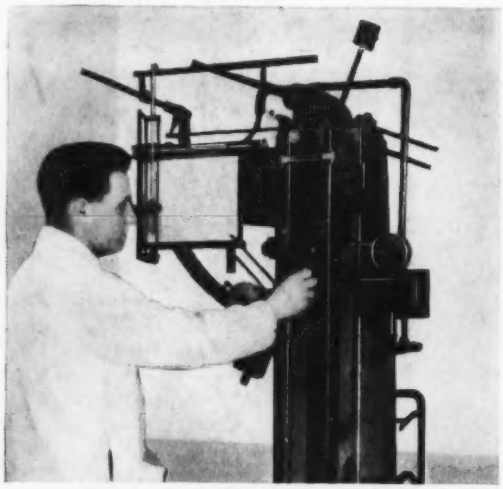

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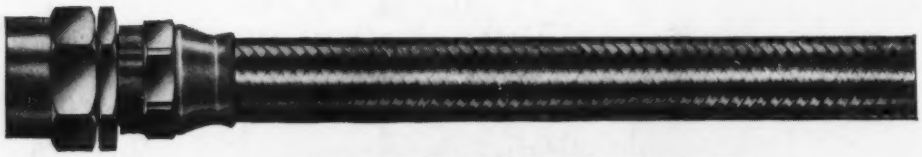

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